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INCREASING THE EFFECTIVENESS OF NAVY RETENTION COMPENSATION BY EVALUATING DIFFERENT AUCTION COMPENSATION FORMATS

by

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June 2015

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With the U.S. military under intense scrutiny to cut costs, the Department of Defense must determine ways to use its limited resources more efficiently. One financial incentive ripe for change is the retention bonus. This compensation tool, used by the military to retain highly qualified individuals, could be harnessed more effectively with an auction mechanism for distribution.

This thesis studies three different types of auctions, and examines which auction would be utilized best by the government as a retention tool. The three auctions analyzed were a sealed bid-discriminatory auction, a sealed bid-uniform auction and a sequential bid-uniform auction.

The results of the experiment showed that discriminatory auctions fared best overall. Sealed bid-discriminatory auctions had a significant savings of 5.1% over sealed bid-uniform auctions and a 10.1% savings over sequential bid-uniform auctions.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACCP	aviation career continuation pay
BCA	Budget Control Act
CO	commanding officer
DOD	Department of Defense
MILPERS	Military Personnel
NFO	naval flight officer
O&M	Operations and Maintenance
TACAIR	tactical air

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—Mike Winters and Terry W. Triplett

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—Mike Winters

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I. INTRODUCTION

Retention bonuses are a tool that businesses use to keep in service those qualified individuals who are critically needed to reach their organization's goals. The military, similar to a civilian company in its desire to retain fully qualified individuals, uses a set of retention devices to keep a portion of its most-qualified service members on active duty. Monetary allowances for these qualified individuals are used to ensure that the member will commit to another several years of service and reach certain milestones in their career.

With an ever-tightening federal budget that is affecting all aspects of the government, especially the Department of Defense, government services must ensure the upmost spending efficiency. When it comes to outlays for retention bonuses, however, the most efficient use of resources is not being undertaken. Retention bonuses are evenly distributed to all members based on previously estimated data, but rarely do they meet the DOD's retention goal. A more efficient and viable option would be for the services to allocate these bonuses with the input of the members—specifically, the values that these members place on remaining on active duty.

The use of auctions, where service members could state their willingness to stay on active duty by submitting a bid, could narrow the gap between what a member is willing to accept to remain on active duty and the government's financial limits concerning bonuses. There are several benefits of utilizing an auction. First, utilizing an auction to determine a retention bonus does a better job tailoring the bonus to a particular community in the U.S. Navy, as it is inefficient to use retention compensation that is not tailored to a particular community (Coughlan, Gates, & Myung, 2014). Second, utilizing an auction helps to retain the right number of people (quantity) and to reduce cost (Coughlan, Gates, & Myung, 2013). This can significantly reduce the over or under retention we currently observe across communities in the U.S. Navy. Finally, while it is outside the scope of this thesis, auction can be modified to redistribute non-

monetary incentives (Coughlan et al., 2013) or to retain a higher quality of service members compared to a regular auction or the status quo (Myung, 2013).

A. RESEARCH SUMMARY

We conducted an experiment to test the performance and behavior of three potential auction formats that can be utilized for retention auctions in the military. The three auctions used in the experiment were a sequential bid uniform auction, a sealed bid uniform auction, and a sealed bid discriminatory auction. These auction formats and the parameters were designed by Prof. Noah Myung at the Naval Postgraduate School.

The results of the experiment showed that discriminatory auction had the lowest procurement cost. Furthermore, it was also the most efficient auction type. Efficiency was measured in terms of procuring or selecting the group of people with the lowest cost. Sealed bid discriminatory auctions had a significant procurement cost savings of 5.1% over sealed bid uniform auctions, and a 10.1% savings over sequential uniform auctions.

The data also shows that it is in the interest of the seller to familiarize their bidders with how treatments work. In most cases, efficiency was increased and procurement costs were reduced as players became more familiar with the bidding process.

B. ORGANIZATION OF STUDY

Chapter II focuses on background for the research, including the current compensation system and why it must be changed. Chapter III describes different types of auction theory and defines the auction types used to conduct the experiment. Chapter IV contains the design and setup of the experiments conducted. Chapter V provides details about the materials and methods that were used. Chapter VI has the results and recommendation, and Chapter VII has the conclusion and final remarks.

II. BACKGROUND

On December 19, 2014, President Barack Obama signed a $585 billion defense bill that focused on balancing combat readiness with tight fiscal controls. This defense bill is one of many over the next several years that will attempt to maintain U.S. military presence in areas of national interest while managing spending limits for all of the service components. The Department of Defense (DOD) monetary limits and financial control measures are part of the president's plan for a massive deficit reform, with a goal of almost $2 trillion in deficit reductions, from cuts to the DOD as well as other sectors of the government (Office of Management and Budget, 2015).

The president's long-term deficit reduction plan has brought about new legislation over the last several years, such as the 2011 Budget Control Act (BCA), that sought to set limits on discretionary appropriations for several years. This law, as well as other novel regulations concerning federal spending, has the DOD looking for ways to meet the congressionally required cost reductions. For the DOD to meet such criteria, policymakers are looking at ways to cut costs from every area, including measures to reduce the size of the military forces, cut healthcare costs, overhaul retirement benefits, set a limit on pay increases, and eliminate acquisition programs.

Ensuring an optimum level of personnel on active duty is one way the DOD will attempt to limit costs in one of its major appropriation categories called Military Personnel (MILPERS) (Congressional Budget Office, 2014). This appropriation houses the basic pay, allowances and retention bonuses that are offered to service members. It currently makes up 27% of military spending, second only to the Operations and Maintenance (O&M) appropriation, which currently represents 40% of all DOD expenditures (Congressional Budget Office, 2014).

To ensure that the military is retaining the correct number of members needed for vital military positions at a minimum cost to the DOD, the services need to create new processes for retention; specifically, they must devise a way to distribute retention bonuses with the highest level of efficiency. This will retain the best service members to fill critical jobs, and come at the smallest financial commitment to the Navy. One way to conduct the distribution of these cash retention bonuses is through a market-based auction, which will allow service members to bid for the bonus they require to remain on active duty. According to Stoskopf, Sever and Nguyen, market-based compensation allows "the flexibility to recognize differing market rates of pay based on performance, skill level or market conditions, and a reasonable level of control over salary costs and internal equity" (Stoskopf, Sever, & Nguyen, 2012).

A. RETENTION BONUS COMPENSATION

1. Current Retention Bonus Process

In 1973, the U.S. military transitioned to an all-volunteer force, eliminating the involuntary draft obligation it used to meet personnel requirements. Since this transition took place, the military has had to offer compensation that would rival similar civilian occupations and offer pay that was within the budget constraints of the DOD. There is constant debate over compensation amounts, and it is based on several factors, including the current tempo of operations, the demand for qualified personnel and the budgetary limits imposed on each service.

Currently, U.S. military members are given several forms of payment for their service. This includes basic pay, which is based on the member's rank and years of service, allowances in the form of a stipend for housing and subsistence, and other special compensation and bonus payments dependent on the member's job and deployment activity. This research focuses on the portion of compensation regarding retention bonuses. These bonuses are offered when a member's obligated service commitment is complete, and the military is attempting to entice them to remain on active duty.

For example, the Navy attempts to retain its aviators with a program called aviation career continuation pay (ACCP). It occurs at around 10 years of service and involves offering a sum of money to those pilots and naval flight officers (NFO) who are at a point in their career where they have to make a decision to remain on active duty or depart the service (PERS-43, 2014). According to the ACCP program, this is generally the first point in their career where they must make this continuation decision.

The ACCP monetary amounts are based on the number of senior officers (referred to as department heads) that each aviation community requires for its future squadron manning requirements. Commonly referred to as the department head bonus, the allotments are based on the type, model and series of aircraft flown and the retention that this community is presently experiencing. In the tactical air (TACAIR) community for example, retention is lower than the pilots required so the retention bonus contract offers $125,000 for an additional five-year term of active duty. Alternatively, the P-3/P-8 community, whose retention is not as dire, currently offers a bonus of $75,000 for an additional five-year commitment. See Figure 1 for all ACCP payouts (PERS-43, 2014). For a comprehensive overview of the ACCP bonus system as well as the standard naval aviator career progression path, reference the thesis by Brett Williams (Williams, 2015).

HM PILOT	$ 75,000
HSC PILOT	$ 75,000
HSL/HSM PILOT	$ 75,000
VAQ PILOT	$ 125,000
VAW/VRC PILOT	$ 125,000
VFA PILOT	$ 125,000
VP PILOT	$ 75,000
VQ (P) PILOT	$ 75,000
VQ (T) PILOT	$ 75,000
VAQ NFO	$ 100,000
VAW NFO	$ 75,000
VFA NFO	$ 75,000
VP NFO	$ 75,000
VQ (P) NFO	$ 50,000
VQ (T) NFO	$ 100,000

Figure 1. FY 2014 ACCP for type/model/series (after PERS-43, 2014)

The ACCP also involves offering a sum of money to commanding officers (CO), who hold the rank of commander and are approaching the decision to retire or continue service through the rank of captain. For these leaders that are approaching the 20-year mark, which makes them eligible for full retirement benefits, a $36,000 bonus is offered to commanding officers that will require them to remain on active duty for at least two more years or until they screen for their next rank (PERS-43, 2014).

2. Problems with the Current Retention Bonus Structure

The ACCP bonus, similar to many bonuses in the DOD, is offered to individuals without their input and is based on current needs in navy manning. In both examples described, there is a lump sum of money that is offered to all

aviators in a community without feedback on the member's personal preferences, or service member needs.

Yet, in reality, there should be some internal or private values that a member would place on their service. Not remarkably, there are members who value their current position so much that they might not even need a bonus to choose to be retained in the Navy. Alternately, there are some who would require a dollar amount in excess of what the government was willing to pay. It is unlikely that this number is exactly the same for all service members.

Additionally there exists a common value between all members who are participating. This could potentially be thought of as the opportunity cost of deciding to take the bonus. How much does one value the time spent contracted to the bonus versus the time they could spend doing something else.

Therefore, a simple bonus system like exists today causes inefficiencies because it does not account for the service member's private and common values. If a member's private value was to be considered in conjunction with the military's bonus it is possible that those individuals would be retained at a far lower cost. In the example above, an aviator who joined the military with the intent of staying in for 20 years would probably need a smaller amount of compensation to remain on active duty. If a TACAIR pilot with ten years in the Navy who always wanted to retire at the 20-year mark would stay on active duty without a bonus, then the Navy would be using a $125,000 retention tool that was unnecessary. The personal desire to serve on active duty, or other private values, if taken into account by the policymakers who decide the size of each retention bonus, could significantly decrease the amount of money that must be appropriated each year for retention bonuses.

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III. AUCTION THEORY

A. BRIEF INTRODUCTION TO AUCTIONS

This chapter will present a brief introduction to the auction types and models used. Our attempt is to cover the models we used and provide enough background information to the reader to be able quickly to understand our methods and results. For more detailed explanations of auctions types and the detailed theory behind their usefulness in specific scenarios, please see Krishna (2010) and Klemperer (2004).

Auctions have played a major role in society for thousands of years. The earliest recorded auction was dated to some 500 B.C. in Babylon. Auctions are used today for everything from commodity markets to online shopping, to the method in which the U.S. government sells bonds to finance its spending (Krishna, 2010, p. 1).

They have been used to provide a means of selling goods at a price point that, in a fundamental sense, clears the market and maximizes the producer and consumer surplus. In practice, however, this simplistic view of auctions is generally never realized due to many internal and external factors that have made them very interesting economic testing grounds for study.

B. AUCTION TERMINOLOGY

1. Private Value and Common Value Auctions

In private value auctions, a bidder holds an independent value of an object that is formed without any information other than that which is personally held. Additionally, this value would have no bearing on any other participant's value of the object. Generally, a typical analogy this type of auction model is that of an art auction. A single bidder might value a piece of art at a certain level that is very different from another, and this value would differ for independent and personal reasons.

Common value auctions generally have the property of having private information that gives bidders a signal to the true value of an object. This true value is common between all participants, but it would not be precisely known. Klemperer uses the example of an oil lease by a drilling company. Its value

> Depends on how much oil is under the ground, and bidders may have access to different geological 'signals' about that amount. In this case a bidder would change her estimate of the value if she learnt another bidder's signal, in contrast to the private value case in which her value would be unaffected by learning any other bidder's preferences or information. (2004, p. 13)

Finally, a combination of private and common values can be used to create a hybrid of these two auction types. In this form, the participant would have both private and common value information to consider when making bid decisions. Goeree and Offerman (2003) argue that this form of auction is more realistic to most real world auctions, citing examples of art having a common resale value or the drilling companies having private value proprietary competitive advantage over their competitors. This form of auction will be the primary focus of our research.

2. Auction Implementations

The ascending bid auction, also commonly called the English auction, is one of the more widely recognized auction forms. Ascending bid auctions are those in which the price of the object being bid on continually is raised by the buyers in the auction. At such a time that the price is at a point that only one bidder still desires to pay that amount or a time limit has expired, the auction is over. This type of auction is seen in many contemporary settings such as art and property auctions or popular Internet locations such as Ebay.com.

Generally, English auctions are performed as forward auctions where bidders are outbidding their competitors by raising their bids. This form of auction can also be run as a reverse auction. In this implementation, the bidders would undercut their competitors bid, until the auction is over. This is most easily

imagined in the case of some kind of procurement auction where multiple bidders are attempting to secure the right to service a single procurer.

Descending bid auctions are slightly different in that they start with a high initial bid, and then the price lowers until such time that an individual calls out in affirmation that they accept the bid or the seller's reservation price has been met, and the auction is over. This form of bidding has also been called a "Dutch Auction" named after the selling of cut flowers at Dutch markets even today (McAffe, McMillan, & Ontario, 1985, p. 702).

First price sealed bid auctions are generally just as they are described by their name. They are the action of submitting a 'sealed bid' in which there is no signal of information between bidders. The winner will be the bidder with the most favorable bid to the seller, and they will pay that price to the seller. First price auctions can create complicated equilibrium behavior as they present a situation where making bids equal to one's own personal value of the object would give a net surplus of 0 to that individual. Therefore, the optimal bid is a tradeoff between the probability of winning the auction and a bidder attempting to increase their net surplus level (Krishna, 2010, p. 14).

Second price sealed bid-auctions are similar to the first price in that the winner of the auction will be the one who bids most favorably to the seller, though the winner will only pay the amount of the second most favorable bid. This type of bidding creates some strategy differences in the way a bidder might approach this type of auction. These auctions are also called "Vickery" auctions after William Vickery, who wrote some of the earliest work on the strategic analysis of auctions.

3. Other Factors

Bidders face many internal and external factors during bid decision making. Many times, these create externalities that limit the efficiency of auction formats. The following paragraphs discuss some of the more common

externalities found in auctions and those that could have accounted for the inefficiencies seen in our data.

Since we are dealing with auctions that contain common values, we must anticipate some amount of inefficiency due to players over-compensating or over-valuing their position. This is referred to as winner's curse. It is a by-product from common value auctions where imprecise information is known of the exact value of an object. The bidder has only a signal of what the true common value is and must rely on this information when making bids. If the bidder is sent a low signal of the true common value and does not have a correction applied, then the bidder may win, but at a net loss in surplus. "Failure to take into account the bad news about others' signals that comes with any victory can lead to the winner paying more, on average, than the prize is worth, and this is said to happen often in practice" (Klemperer, 2004, p. 14). This failure of correctly estimating the exact value is the winner's curse.

Payout rules affect decision making while participating in an auction. The two forms we use in our study are discriminatory and uniform price payouts. In discriminatory auctions, winning players will be rewarded with compensation equaling their bid amount. In uniform-type auctions, all winning players are paid the same amount. In our uniform auction experiments, players were awarded an amount equal to the first excluded bid in each group.

Reserve prices also affect a bidder's efficiency. This term refers to the minimum value at which the seller will agree to sell the item. This idea plays a role with first and second price bidding, as it can affect the surplus gained by the bidders. Reserve prices have a more marginal affect in first price auctions, as any bidder who values the item less than the reserve price would not profit by making a bid at all (Krishna, 2010, p. 21).

All bidders must make risk decisions. Risk deals with the degree to which a person makes decisions based on the information provided. Risk aversion, neutrality, or prone-type individuals will approach situations in different ways, and

their bidding strategies will ultimately depend on this trait. Our experiment attempts to identify a bidder's risk tolerance by having them participate in a small game to which they will risk a known amount of money in a controlled way. From this data, we can examine their actual bids in the auction experiments and deduce if their bids were optimal based on this calculated preference.

Finally, we must account for or attempt to prevent any form of collusion from the participants. Collusion deals with the incentives provided by participants sharing information with each other outside the realm of the experiment. This behavior can lead to unfair advantages to those that collude. Krishna (2010) labels the formation of these groups as "bidding rings." He delves into the subject by exploring models of collusion as a "mix of cooperative and non-cooperative game theory" where the standard efficiency rules of basic auctions change (p. 157). This level of detail is outside the scope of this experiment, and we handle it by randomizing groups of players and monitoring the experiment in a lab setting.

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IV. EXPERIMENT DESIGN

In this chapter, we will analyze the auctions that were chosen for the research, how these auctions created six treatments that were used for the experiment, and the details of their design.

A. OVERVIEW

1. Types of Auctions and Their Treatments

As stated in the model, we compared three different auctions. These three auction types were a sealed bid-discriminatory auction, a sealed bid-uniform auction, and a sequential bid-uniform auction. Each auction had two treatments where it was conducted with both a private and common value, and then conducted using a private value only. Overall, our experiment was a 2x3 design with three auctions, each auction conducted in two different ways creating six treatments (Table 1).

Treatment Type	Abbreviation
Sealed Bid Discriminatory (Private and Common Value)	D_P+C
Sealed Bid Uniform (Private and Common Value)	U_P+C
Sequential Uniform (Private and Common Value)	S_P+C
Sealed Bid Discriminatory (Private Value Only)	D_P
Sealed Bid Uniform (Private Value Only)	U_P
Sequential Uniform (Private Value Only)	S_P

Table 1. Six treatments conducted during experiment

Throughout the experiment, up to three of the auctions were performed per session, with a varying amount of rounds per auction group. The treatments picked for each session ensured that each treatment was conducted first at least once during the course of this experiment. The number of volunteers who participated in each session had to exceed eight in total, and had to be a multiple of four. This was because each round grouped four participants at random to bid

against each other for each round. Figure 1 shows the number of volunteers who performed at each session with the type of treatments they participated in, and how many rounds were conducted. At the end of each round, the participants at the session would once again be randomly matched with another set of participants, creating a new foursome that would bid against each other in the next round. There was no way for the participants to know whom they were bidding against at any time (Figure 2).

Session	Number of Volunteers	Auctions Performed	Number of rounds per Auction
1	16	Sealed Bid - Discriminatory	10
		Sequential Bid - Uniform	5
2	12	Sequential Bid - Uniform	10
		Sealed Bid - Uniform	3
3	16	Sealed Bid - Uniform	10
		Sealed Bid - Discriminatory	5
4	12	Sealed Bid - Uniform	10
		Sequential Bid - Uniform	10
5	16	Sequential Bid - Uniform	10
		Sealed Bid - Discriminatory	5
6	16	Sequential Bid - Uniform (Private only)	10
		Sequential Bid - Uniform	10
		Sealed Bid - Discriminatory	10
7	16	Sealed Bid - Uniform (Private only)	10
		Sealed Bid - Uniform	10
		Sequential Bid - Uniform	10
8	12	Sealed Bid - Discriminatory (Private only)	10
		Sealed Bid - Discriminatory	10
		Sealed Bid - Uniform	10
9	16	Sealed Bid - Discriminatory	10
		Sealed Bid - Uniform	10
		Sealed Bid - Discriminatory (Private only)	10
10	8	Sequential Bid - Uniform	10
		Sealed Bid - Uniform	10
		Sealed Bid - Discriminatory	10

Figure 2. Number of volunteers, treatment types and rounds per treatment

B. SEALED DISCRIMINATORY AUCTION

A sealed bid discriminatory treatment meant that the participants could only submit their bid once with no possibility of an update. The participants had

no idea how much the other members in their group were bidding. When the round was over, the results of that round revealed the winning bid. This was the only time other bids were revealed to the sealed bid auction participants.

1. Participant's Role

The participant played the role of a private contractor that was seeking to sell its services to a fictitious corporation. Each round of every treatment represented a different service the participant was trying to sell to the corporation. The volunteers for each session were divided into groups of four, with the two lowest bidders winning the round for that treatment. We informed the participants that they had the ability to win every round and their company was only limited by the amount of costs that were to be incurred, and not on the number of workers they employed.

2. Private and Common Costs

The bidder's cost for providing a service consisted of a private cost and a common cost. Before bidding, the bidders were told their private cost and an estimate of the common cost. This private cost (internal cost) was randomly chosen and uniformly and independently distributed among all participants. The range for the possible internal costs was between 75 and 125 francs. This range was based off a similar auction performed by Goeree and Offermanm (2002).

The bidders were only given an estimation of their common cost (external cost). The actual common cost that the two winning bidders would have to pay for the job was an average of all four bidders' estimated common costs. For each bidder, the estimated common costs were drawn randomly and independently from uniform distribution between 75 and 125. Consequently, the total cost in each treatment fell between a range of 150 (assuming a private cost of 75 and an average external cost of 75) through 250 francs (assuming a private cost of 125 and an average external cost of 125). We also ran treatments using only private costs as a benchmark for the analysis of using private and common values.

3. Revenue and Profit Earned

For the two lowest bidders, the revenue received was equal to his or her bid. Profit was determined by taking the revenue that was received for winning the round and subtracting the private (internal) cost and subtracting the common (external) cost, if it was applicable to that particular treatment. No revenue was earned for the two losing bidders and they also did not incur any cost. Figure 3 shows an example of how profit was calculated for the discriminatory auction. Depending on the amount of revenue that the bidder received, it was possible for the profit to be negative for each round. Negative profits decreased the amount of money the participants earned during the session.

Discriminatory Auction				
Company ACME I looking for a total of two (2) contractors				
Bidder	Bid	Internal Cost	External Cost Estimate	
1	250	100	120	
2	215	105	100	
3	260	90	125	
4	280	80	115	
			Average External Costs	115
	=winning bid			
Profit = revenue - internal job cost - average estimate of external job cost				
Profit				
	Revenue	Int. costs	Avg. Ext costs	Profit
Bidder 1	250	100	115	35
Bidder 2	215	105	115	-5

Figure 3. Discriminatory auction payout

4. Tiebreakers and Sample Quiz

In the event of a tiebreaker, where two bidders had bid the exact same price for the contract, the tie was broken by a computer random number generator, where each person who tied had an equal chance to get the contract.

C. SEALED UNIFORM AUCTION

The sealed bid uniform auction was conducted in the same manner as the sealed bid discriminatory auction. The only difference in this auction was that the participants were paid with the uniform auction guidelines.

1. Revenue and Profit Earned

For the sealed bid-uniform auction, the two winners of the round would be paid revenues equal to the first excluded bid (or third lowest bid) for that particular round. Profit for the sealed bid uniform treatments was equal to the revenue they received, minus their private cost and the average common cost (see Figure 4 for a uniform auction payout example).

Uniform Auction				
Company ACME I looking for a total of two (2) contractors				
Bidder	Bid	Internal Cost	External Cost Estimate	
1	230	125	100	
2	225	105	120	
3	235	90	125	
4	280	80	115	
			Average External Costs	115
		=winning bid		
Profit = revenue - internal job cost - average estimate of external job cost				
Profit				
	Revenue	Int. costs	Avg. Ext costs	Profit
Bidder 1	235	125	115	-5
Bidder 2	235	105	115	15

Figure 4. Uniform auction payout

D. SEQUENTIAL UNIFORM AUCTION

The sequential bid auction was similar to the sealed bid auctions with the following differences. The sequential auction allowed participants to bid against each other with the ability to change their bid throughout the round. The individual's bid could be increased or decreased as many times as desired within

the time limit of each round. Also, the sequential auction allowed the competing participants to see each bidder's current bid as they were updated throughout the round. When time expired, the two participants with the first and second lowest bid won that round.

1. Time Limit for Each Round

Unlike the sealed bid auctions, the sequential bid auction had time constraints for each round. For the sequential bid uniform auction, the participants had 90 seconds to make their bid in the first round, 60 seconds to make their bid in rounds two through four, 45 seconds to make their bid in rounds five through seven, and 30 seconds to make their bid in round eight through ten. The time started after everyone submitted his or her initial bid. The time was purposefully decreased in later rounds of the sequential auction to account for the learning curve of the participant's bidding behavior.

2. Revenue and Profit Earned

For the sequential bid-uniform auction, the two winners of the round were paid in the same manner as the sealed bid-uniform auction.

V. MATERIALS AND METHODS

(1) Auction Computer Program

Experiments were conducted using zTree auction program (Fischbacher, 2007).

(2) Location and Test Subjects

The experiment was performed at two locations. The first five sessions were conducted at the Naval Postgraduate School and the second five sessions were conducted at the University of Virginia. The participants were recruited using local recruiting materials (emails and flyers). A total of 140 people participated in the experiment.[1] At the end of the experiment, all test subjects were paid cash based on the results of the decisions the participants made during the entire session.

(3) Computer Setup

The computers that were used for the experiment were standard university desktops located in one computer lab. There were a total of eight to 16 computers used for the experiment, depending on the number of volunteers. This allowed the auctions to have two or four groups of four participants randomly selected each round. To prevent participants from seeing the possible bidding of the other participants around them, cardboard computer dividers were used ensure anonymity between all the participants (see Figure 5). The participants were also provided calculators, pens and scratch paper in the event it was required.

[1] We were only able to conduct experiments in multiples of four people.

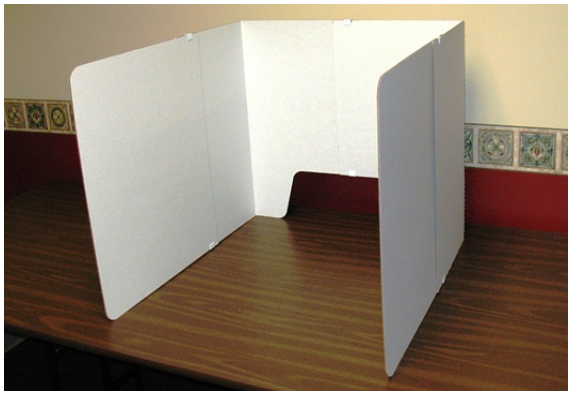


Figure 5. Cardboard cubicle computer dividers

(4) Conversion Rate

All costs and earnings associated with the experiment were measured in "francs," which was a fictitious currency that had an exchange rate of $.10 per 1 franc. At the end of the session, all participants were paid in U.S. currency equal to the amount they earned during the course of the entire session.

VI. ANALYSIS AND RESULTS

Treatment data was extracted from the experiments and analyzed utilizing Microsoft Excel. The analysis attempts to break data down and examine how the treatments could be interpreted in three main focus areas. The first area was a procurement cost component that sought to show how much the different treatment types would deliver revenue to the bidders and ultimately cost to the auctioneer, which we refer to as procurement costs. The second focus was on bidder efficiency and attempts to show how well the lowest cost bidders were selected relative to the group they were matched against. The third displays behavior of bidders mapping their estimated costs and actual costs with respect to the bids they chose.

All three areas include cost data aggregated from all sessions and treatments. The aggregated data attempts to highlight major attributes of the treatment types and provides a top-down view of our results. Also, we examine data collected from treatments conducted as the first treatment for a particular session. This data was selected in order to limit any learning the bidder might have attained from previous treatments. Each of our first treatments conducted ten periods each and is broken into period segments. The first five periods were compared to the second five periods to show any efficiency gain as subjects began to become more proficient in the bidding process.

Private value only versions of each treatment are provided as a contrasting analysis for comparison.

A. PROCUREMENT COST

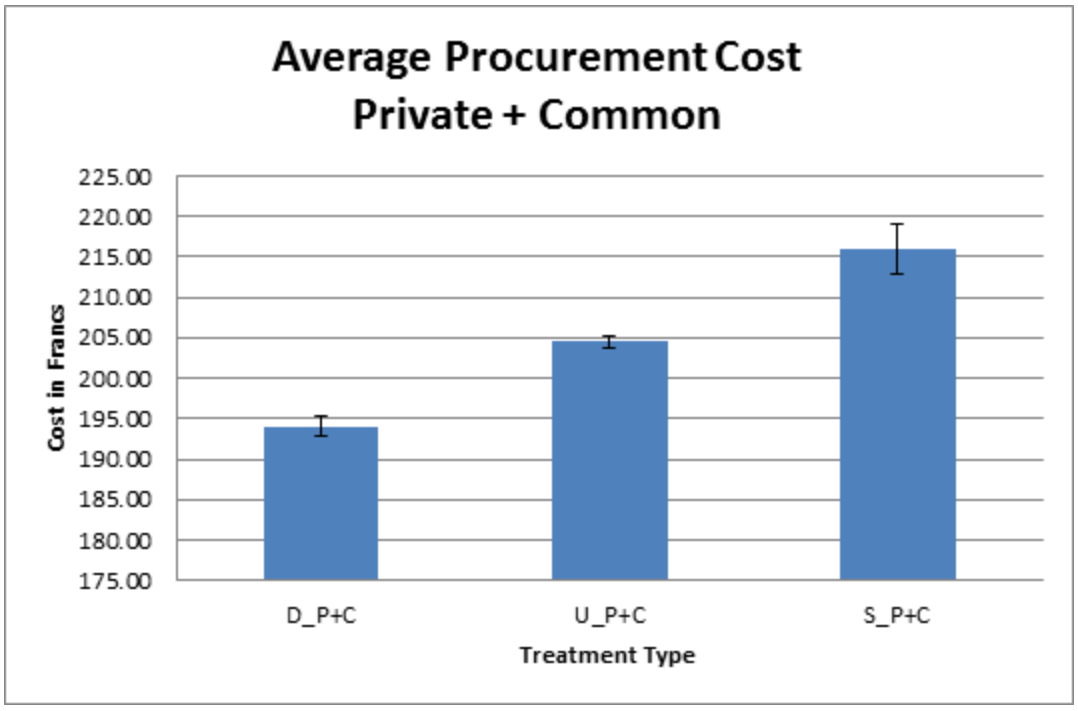
This section looks at the amount paid to subjects with respect to the particular treatment types used. The term ‘procurement cost’ is used to represent the amount of currency a buyer would have to pay to the winners in the auction. We first examine the average procurement cost for each treatment type and then look at the ratio of procurement costs to the total cost incurred by the winners.

As discussed in Chapter III, the amount the winners are paid differs between discriminatory and uniform treatment types. In discriminatory treatments, bidders are awarded the amount they bid if selected to win. In uniform treatments, the winning bidders are paid uniformly and, in the case of this experiment, were paid the first excluded bid in the group of bidders per period. Either way, in this section, we focus on the procurement cost—the total amount spent by the buyer to procure these services from the winners of the auction.

1. Overall Procurement Costs

Overall procurement costs were calculated by taking the average of 'revenue earned' from all winning bidders over all treatments in that respective treatment type.

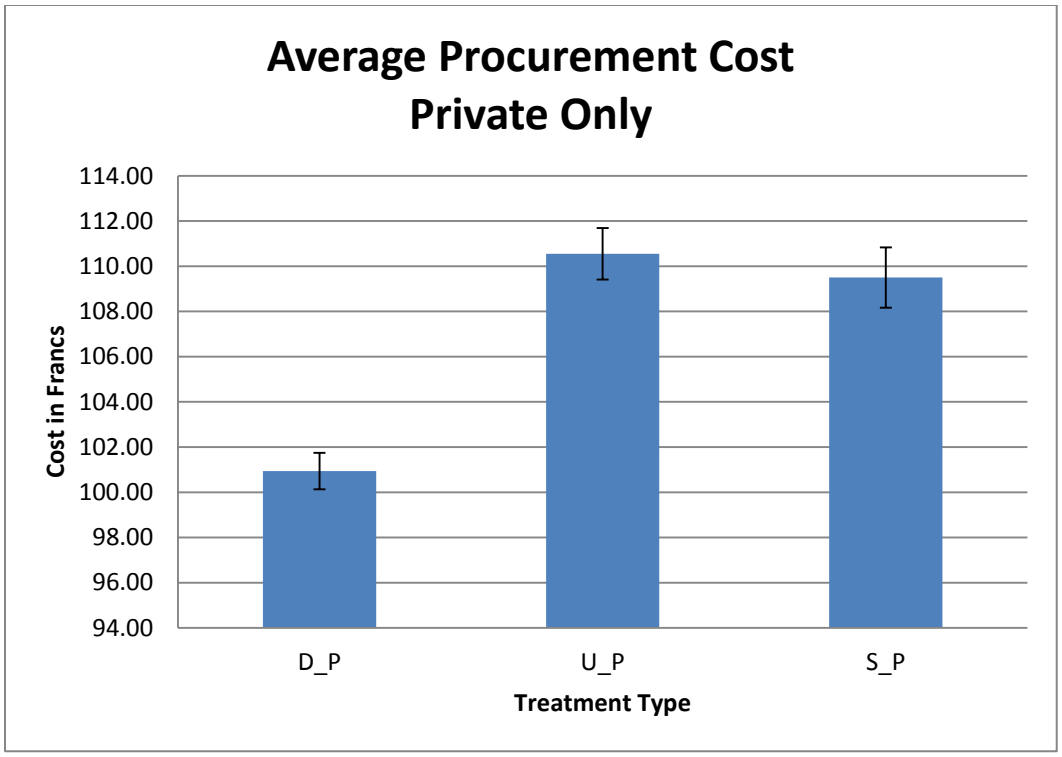
When private and common values were used, sealed bid discriminatory showed to have a significant procurement cost savings of 5.1% over sealed bid uniform, and a 10.1% edge over sequential uniform. See Table 2.



Treatment Type	Average Procurement Cost	StdDev Procurement Cost	Number of Observations	Std Error
D_P+C	194.06	23.58	420	1.1504216
U_P+C	204.49	14.82	418	0.724791
S_P+C	215.94	63.48	440	3.0261578

Table 2. Average procurement cost (private + common)

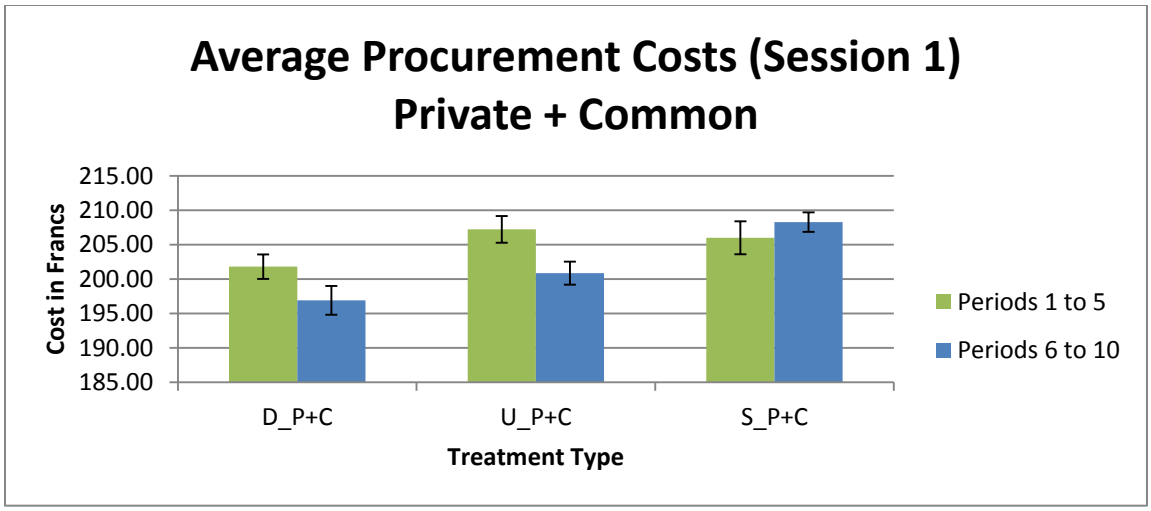
With respect to private value only auctions, discriminatory still retains the lowest average cost treatment type by a considerable margin, yet uniform performs slightly worse with respect to the common value version. Discriminatory was 9.5% better than uniform and 8.5% better than sequential for the private treatments. This could be due to more efficient bidding by the subjects because their costs were known to them. See Table 3.

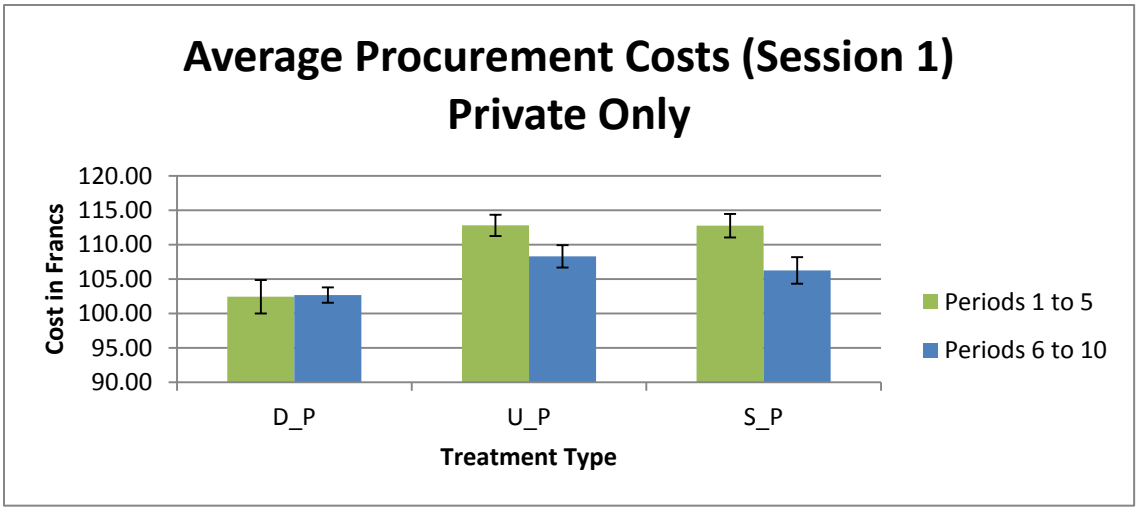


Treatment Type	Average Procurement Cost	StdDev Procurement Cost	Number of Observations	Std Error
D_P	100.94	9.55	140	0.8070992
U_P	110.55	10.21	80	1.1409939
S_P	109.50	11.95	80	1.3362047

Table 3. Average procurement cost (private only)

Looking at only the treatments that were conducted first in the session shows that, over time, subjects were able to learn how to bid more effectively, and in most cases procurement costs went down. This would suggest that if these treatments were to be used on a larger scale, ensuring that adequate training was available to those participating would be in the interest of the seller. See Table 4.


Average Procurement Costs (Session 1)
Private + Common
215.00
210.00
205.00
200.00
195.00
190.00
185.00
Cost in Francs
D_P+C
U_P+C
S_P+C
Treatment Type
Periods 1 to 5
Periods 6 to 10


Average Procurement Costs (Session 1)
Private Only
120.00
115.00
110.00
105.00
100.00
95.00
90.00
Cost in Francs
D_P
U_P
S_P
Treatment Type
Periods 1 to 5
Periods 6 to 10

	Treatment Type	Average Procurement Cost	StdDev.s of Procurement Cost	Count of Procurement Cost	StdErr
Period 1 to 5	D_P+C	201.80	15.95	80	1.78339741
	U_P+C	207.22	16.20	70	1.93616513
	S_P+C	206.00	22.73	90	2.39550661
	D_P	102.43	13.28	30	2.42528981
	U_P	112.80	9.75	40	1.54222616
	S_P	112.75	10.86	40	1.71634301
Period 6 to 10	D_P+C	196.90	18.69	80	2.08952323
	U_P+C	200.86	13.98	70	1.67087903
	S_P+C	208.27	13.49	90	1.42167983
	D_P	102.67	6.13	30	1.11966059
	U_P	108.30	10.27	40	1.62362368
	S_P	106.25	12.24	40	1.93541555

Table 4. Average procurement costs (session 1)

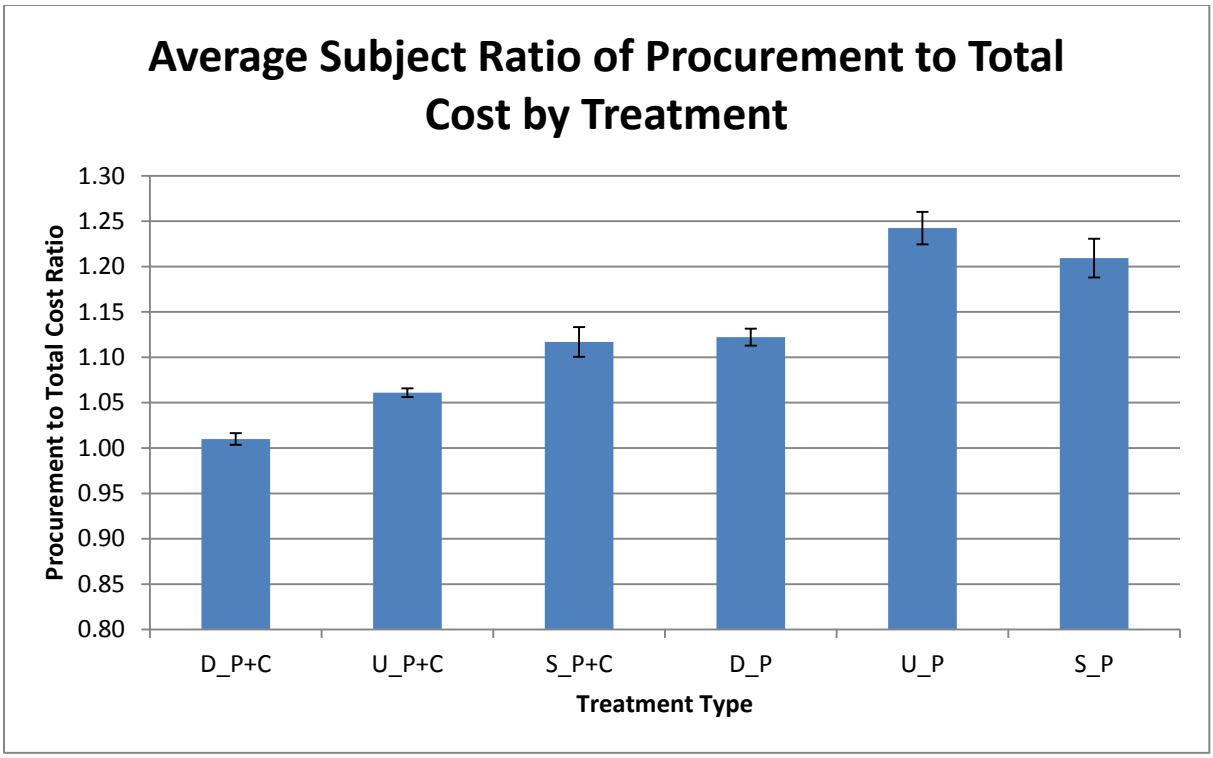
Overall, from a procurement perspective, discriminatory-type treatments appear to have the lowest cost per average and, once subjects had some experience placing their bids, the total procurement costs would decrease. The amount of learning taking place is seen in most treatments and evidenced by the general decrease in standard error of the averages.

2. Ratio of Procurement Cost to Total Cost

Up to this point, we have only looked at total procurement costs and averages of the finds. Here, we look at a ratio of those costs against the total cost the subject would incur when their bid was selected to win. This puts the data in the same unit for comparison, even between private only and private + common cost treatments. This ratio is calculated by dividing the procurement cost for each winning bidder and dividing by the total cost associated with each win. In the case of treatments using the private and common costs, this is the sum of that private cost and the actual common cost of the particular procurement. This ratio for the individual winner is then averaged across all such ratios of that same treatment type.

$$Ratio\ of\ Procurement\ to\ Total\ Cost\ for\ subject\ i\ = \frac{Procurement\ Cost_i}{Total\ Cost_i}$$

This would imply that a higher ratio would mean more cost to procure a bidder per dollar of cost to that bidder. Again, sealed bid discriminatory holds an edge on the other treatment types. For example, when looking at D_P+C treatment, winners' revenues were about 1% higher than their total cost, but the winners from the S_S+C were receiving revenues of about 12% higher than their total cost. See Table 5.



Treatment	D_P+C	U_P+C	S_P+C	D_P	U_P	S_P
Average	1.01	1.06	1.12	1.12	1.24	1.21
Stddev.s	0.13	0.10	0.34	0.11	0.16	0.19
Count	420	418	440	140	80	80
Std Err	0.0065	0.0048	0.0164	0.0093	0.0179	0.0213

Table 5. Average subject ratio of procurement to total cost

B. EFFICIENCY

Efficiency of treatment types is analyzed to get a sense of how "well" the treatments were able to select the lowest-cost bidders to win each auction. Efficiency is measured here by looking at the bidders at the group level and creating a ratio of the sum of the two winners' internal private costs minus the two highest private costs, compared to a baseline of the sum of the two actual lowest private cost bidders minus the two highest bidder private costs. An overall efficiency for each treatment was calculated by taking an average of all such efficiencies. High efficiency scores are received when the auction is won by the individuals having the lowest private cost.

$$Efficiency\ of\ Group\ in\ Treatment\ =\ \frac{P_{win} - P_{max}}{P_{min} - P_{max}}$$

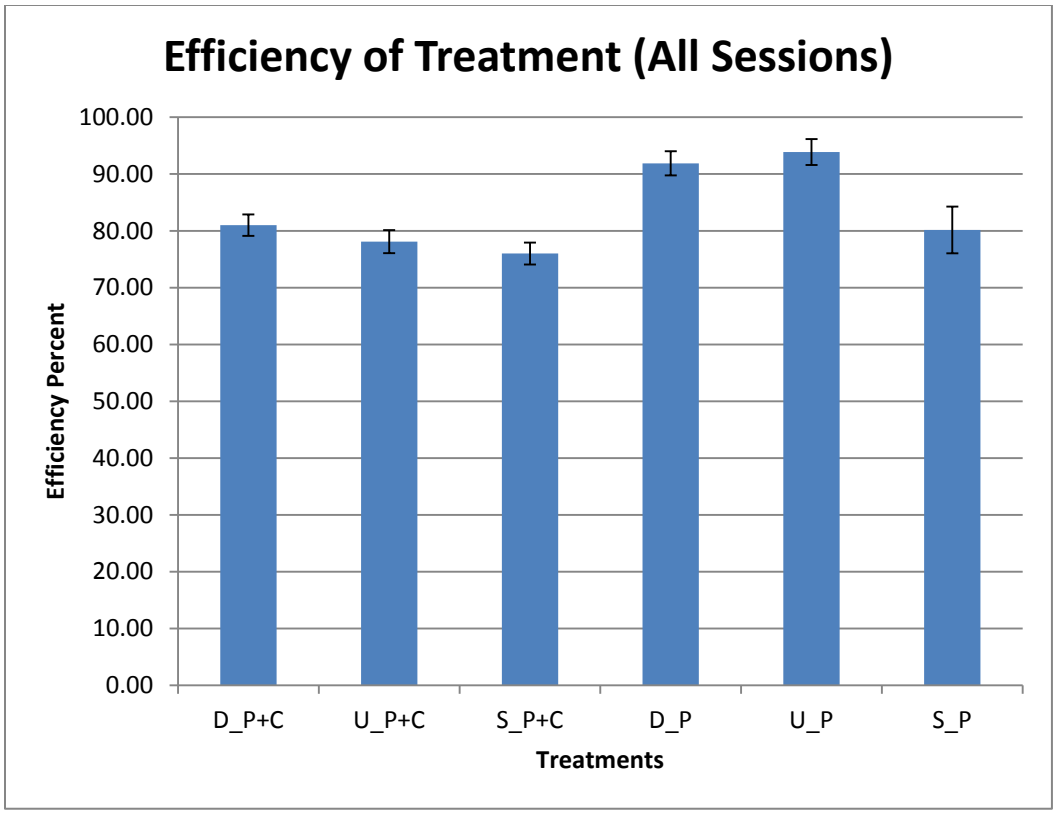
where:

$$P_{win}\ =\ Sum\ of\ private\ costs\ of\ two\ winners\ in\ group$$

$$P_{max}\ =\ Sum\ of\ two\ highest\ private\ costs\ in\ group$$

$$P_{min}\ =\ Sum\ of\ two\ lowest\ private\ costs\ in\ group$$

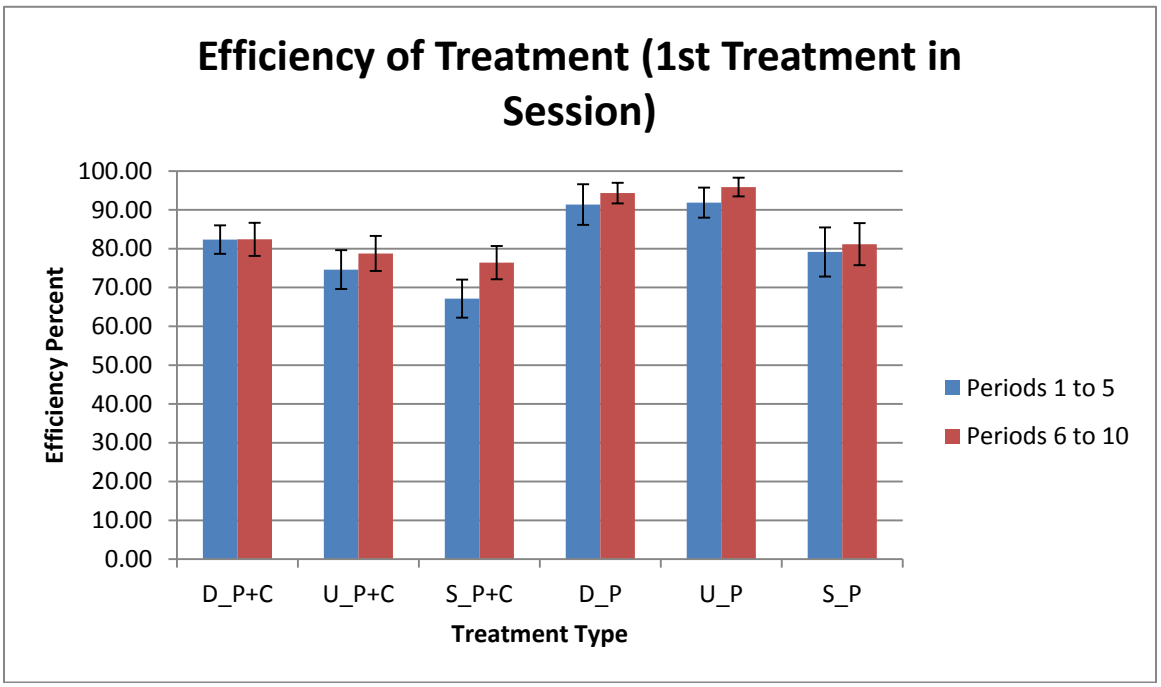
Overall, discriminatory treatments fared best when using private and common values. Uniform seemed to do better when only using private values. In addition, the efficiency levels were higher when the auctions were conducted with only the private values compared to private and common values. See Table 6.



Treatment	D_P+C	U_P+C	S_P+C	D_P	U_P	S_P
Mean	80.99	78.10	76.00	91.88	93.86	80.16
StdDev.s	25.98	27.87	28.61	17.77	14.38	26.01
Count	190	189	220	70	40	40
StdErr	1.8847	2.0270	1.9292	2.1242	2.2744	4.1127

Table 6. Efficiency of treatments (all sessions)

Table 7 data suggests that players were more efficient as the treatment progressed. When looking at data from the first treatment of the session, the average efficiency increases in all treatment types. This might be due to subjects learning how to bid more effectively as the treatment progresses.



	D_P+C		U_P+C		S_P+C		D_P		U_P		S_P	
	1 to 5	6 to 10	1 to 5	6 to 10	1 to 5	6 to 10	1 to 5	6 to 10	1 to 5	6 to 10	1 to 5	6 to 10
Mean	82.34	82.41	74.61	78.77	67.12	76.41	91.37	94.32	91.86	95.87	79.15	81.16
StdDev.s	23.16	26.98	29.56	26.66	32.84	28.84	20.33	10.26	17.32	10.78	28.30	24.20
Count	40	40	35	35	45	45	15	15	20	20	20	20
StdErr	3.6626	4.2667	4.9958	4.5059	4.8949	4.2987	5.2493	2.6500	3.8728	2.4115	6.3280	5.4119

Table 7. Efficiency of treatment (1st treatment of session)

C. BEHAVIOR

This section deals with the behavior of bidders when presented with information. Behavior is analyzed by graphing bids against their associated cost. We examine this in three ways. The first is by graphing the bid versus the total cost associated with each treatment period. In the case of the treatments with common values, we also look at what the bid was in relation to the estimated total cost the subject is provided as the period is being conducted. Finally, we show data that is drawn from treatments that were the first treatment of the session, as was done in other sections. This is provided again to show a baseline of the subjects' relative progression in being more efficient as the treatment is conducted with minimal prior experience in other treatment types.

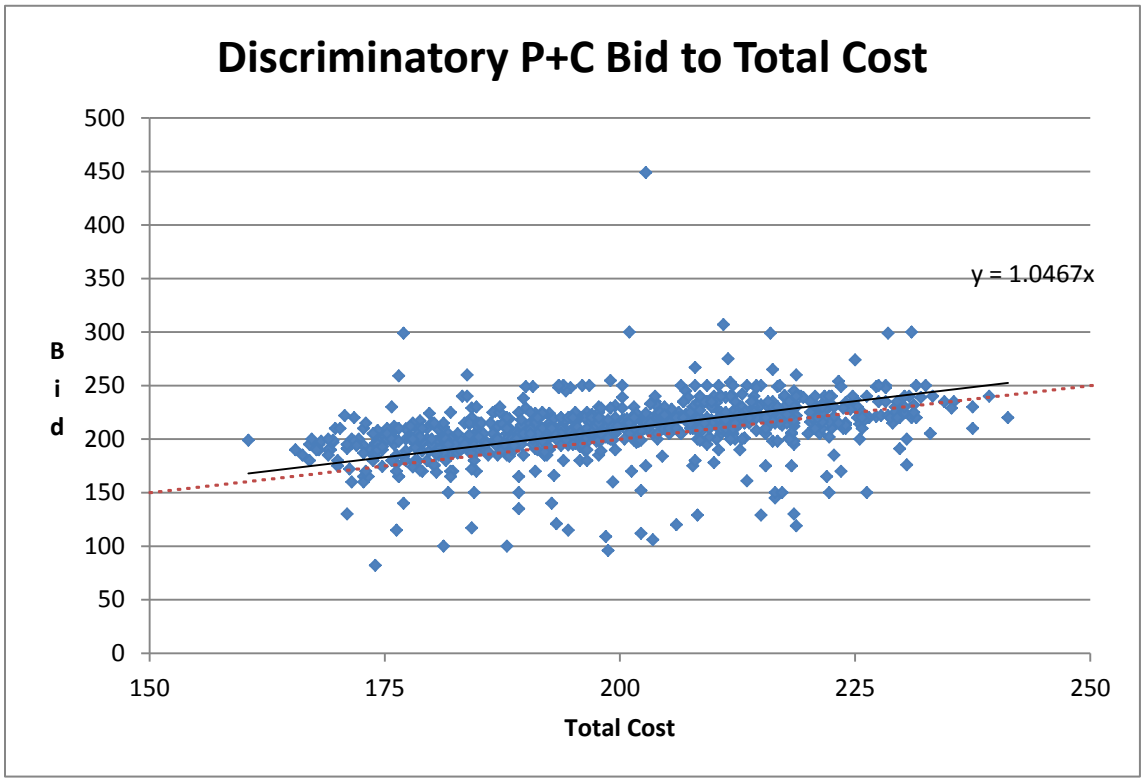
Data for the private value auctions is also provided at the end of this section. As there are no common values for these treatment types, there is no estimate of costs and therefore no graphs for these.

Notes for all graphs in this section:

- Black line denotes regression of data set. Equation is regression equation.
- Red line denotes 45 degree line through 0 intercept (Y=X).
- All bid data over 500 francs is not shown to increase readability. For all treatments, this cut-off represents greater than three standard deviations away from the mean and this data is considered outliers.

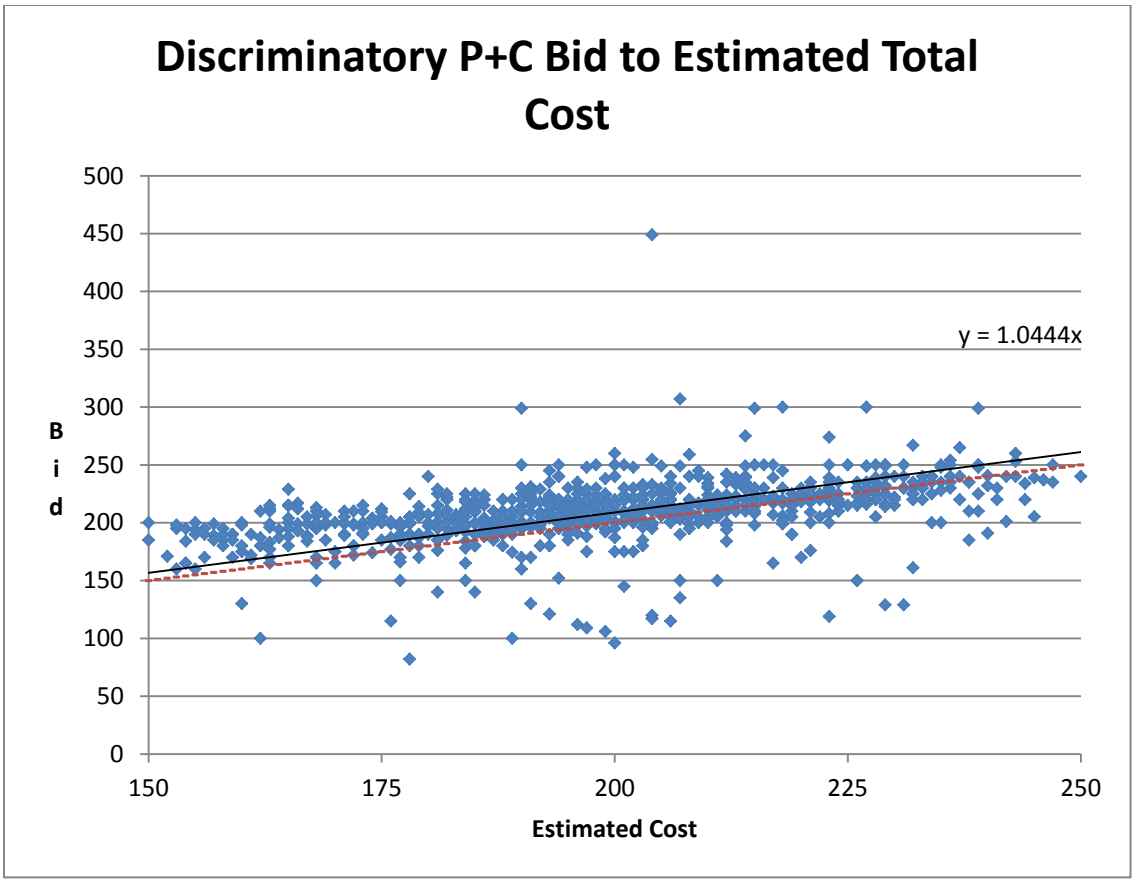
1. Discriminatory Private and Common Value

Discriminatory private and common value treatments showed bidders generally bid roughly 4.67% over their actual costs and 4.4% over their estimated costs (Tables 8 and 9). This may suggest that bidders are bidding too low in the discriminatory auction format. Additionally, Tables 10 and 11 show that, after some learning, bidders would bid more closely to their actual costs.



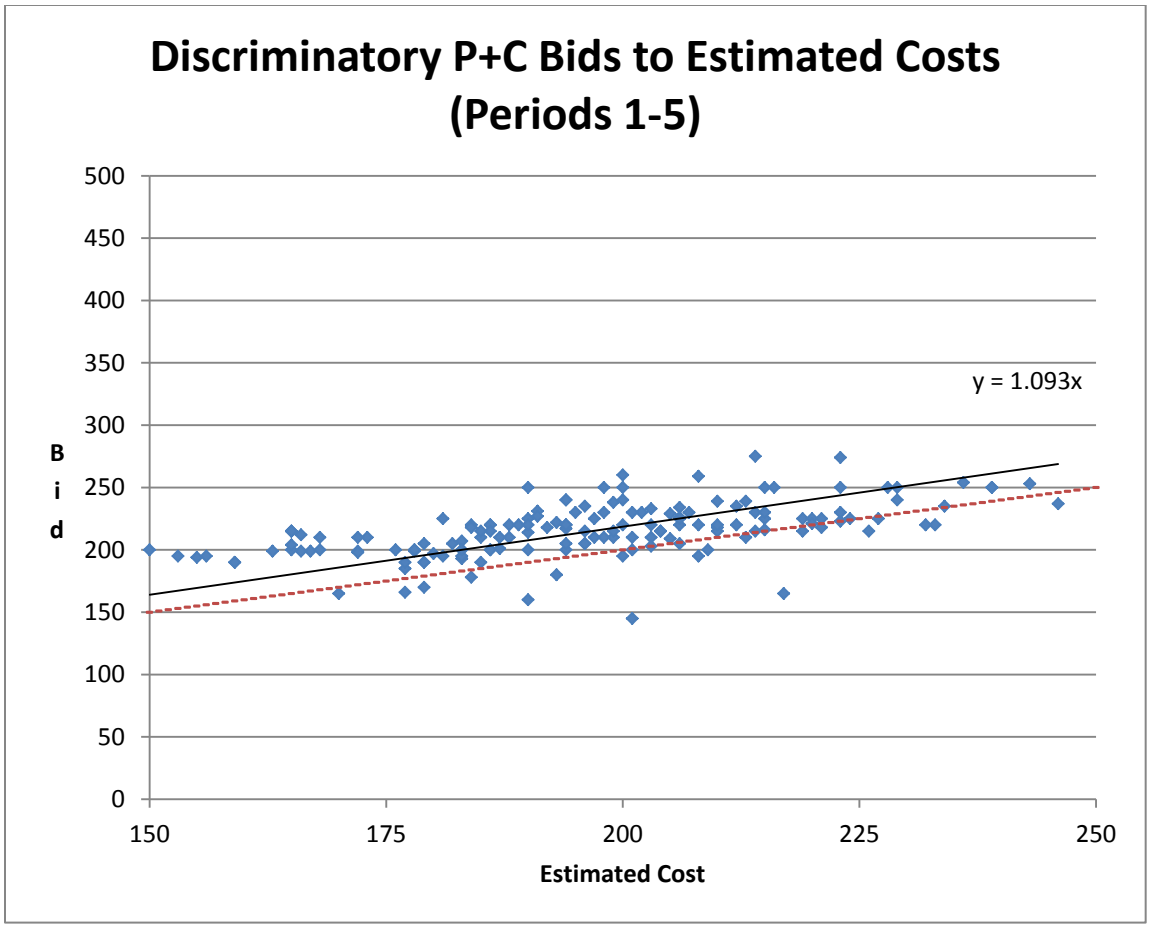
D_P+C	Bid
Average	209.1293
StdDev.s	26.98549
Count	840
StdErr	0.931088

Table 8. Discriminatory private and common bid to total cost



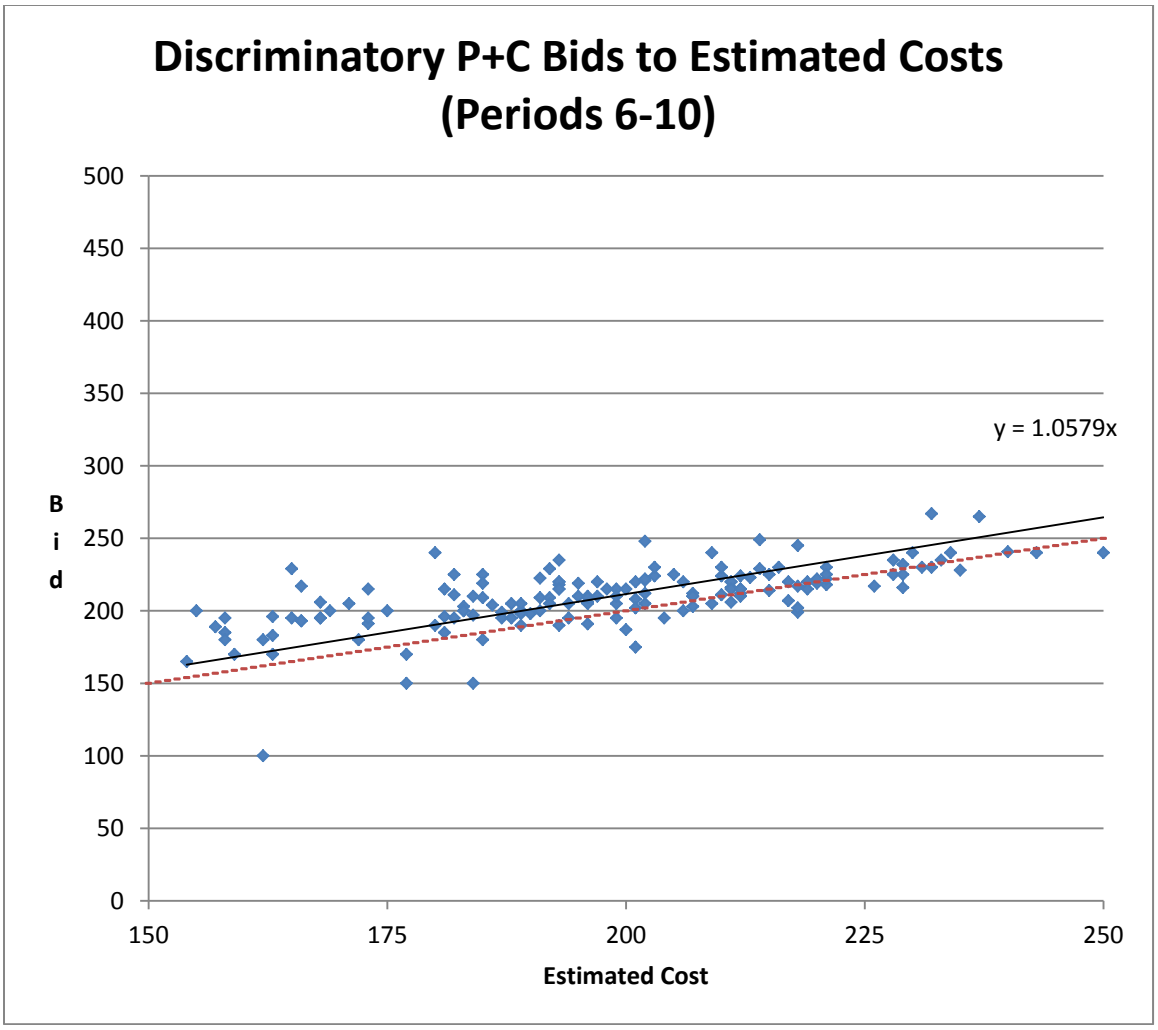
D_P+C	Bid
Average	209.1293
Stddev.s	26.98549
Count	840
StdErr	0.931088

Table 9. Discriminatory private and common bid to estimated total cost



D_P+C	
1 to 5	Bid
Average	215.60
StdDev.s	21.19
Count	160
StdErr	1.6756

Table 10. Discriminatory private and common bid to estimated total cost (periods 1 to 5)



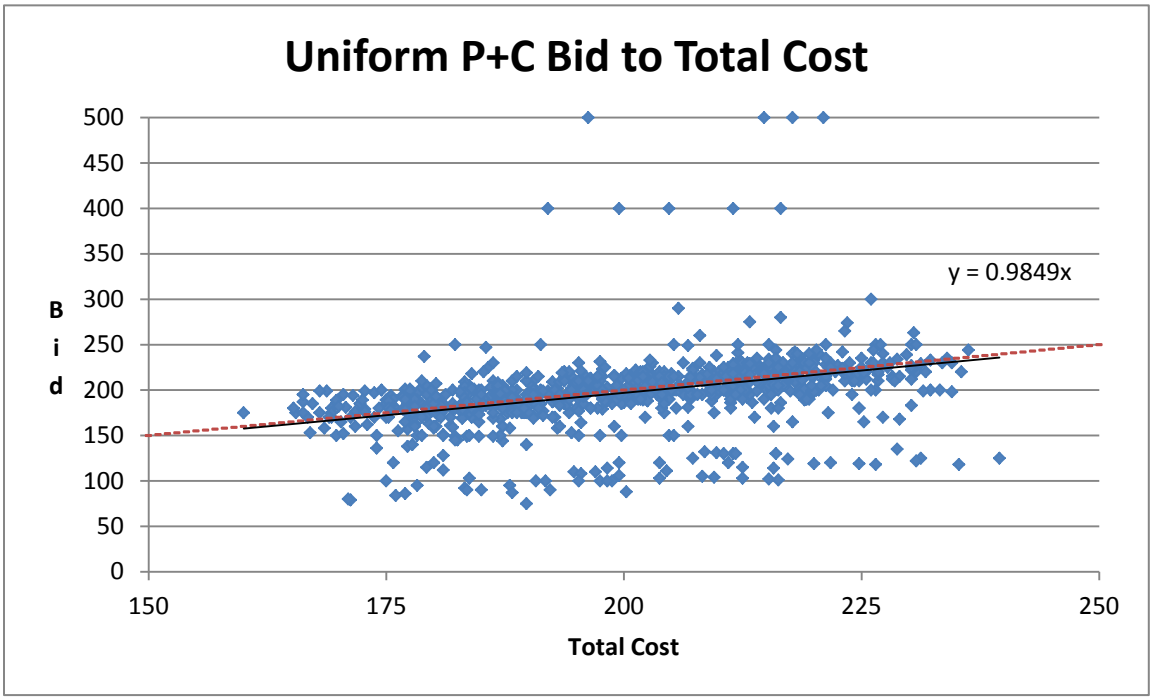
D_P+C	
6 to 10	Bid
Average	209.58
StdDev.s	20.86
Count	160
StdErr	1.6492

Table 11. Discriminatory private and common bid to estimated total cost (Periods 6 to 10)

2. Uniform Private and Common Value

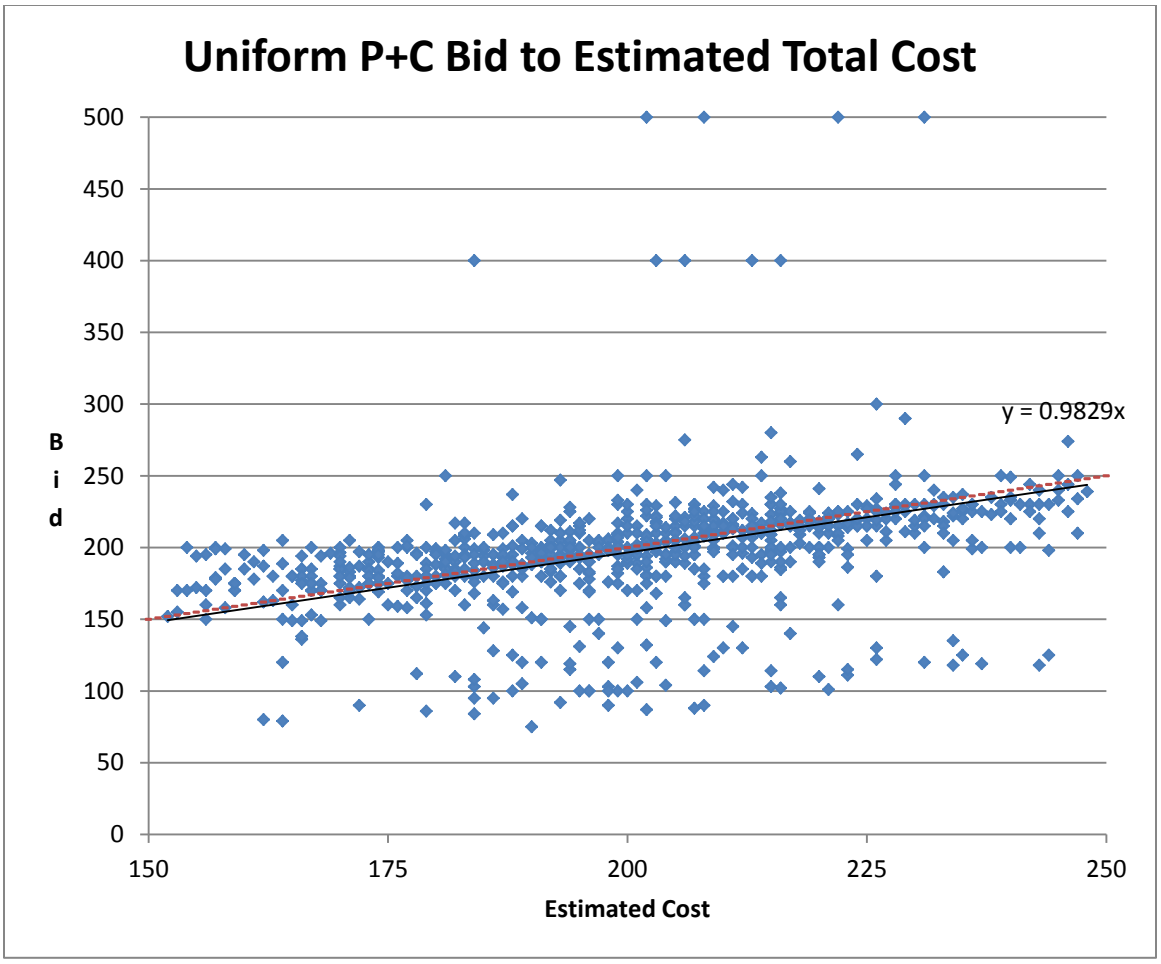
Uniform auctions allow a bit more strategy when placing bids, as one will receive payout of the first excluded bid. Compared to the discriminatory auctions, there is a noticeable trend to bid below cost. On average, players bid roughly 98% of their estimated costs in hopes that the first excluded bid would be higher (Tables 12 and 13).

Players also seemed to be consistent in their bidding strategy through the rounds. There is little change from the first five periods to the next (Tables 14 and 15).



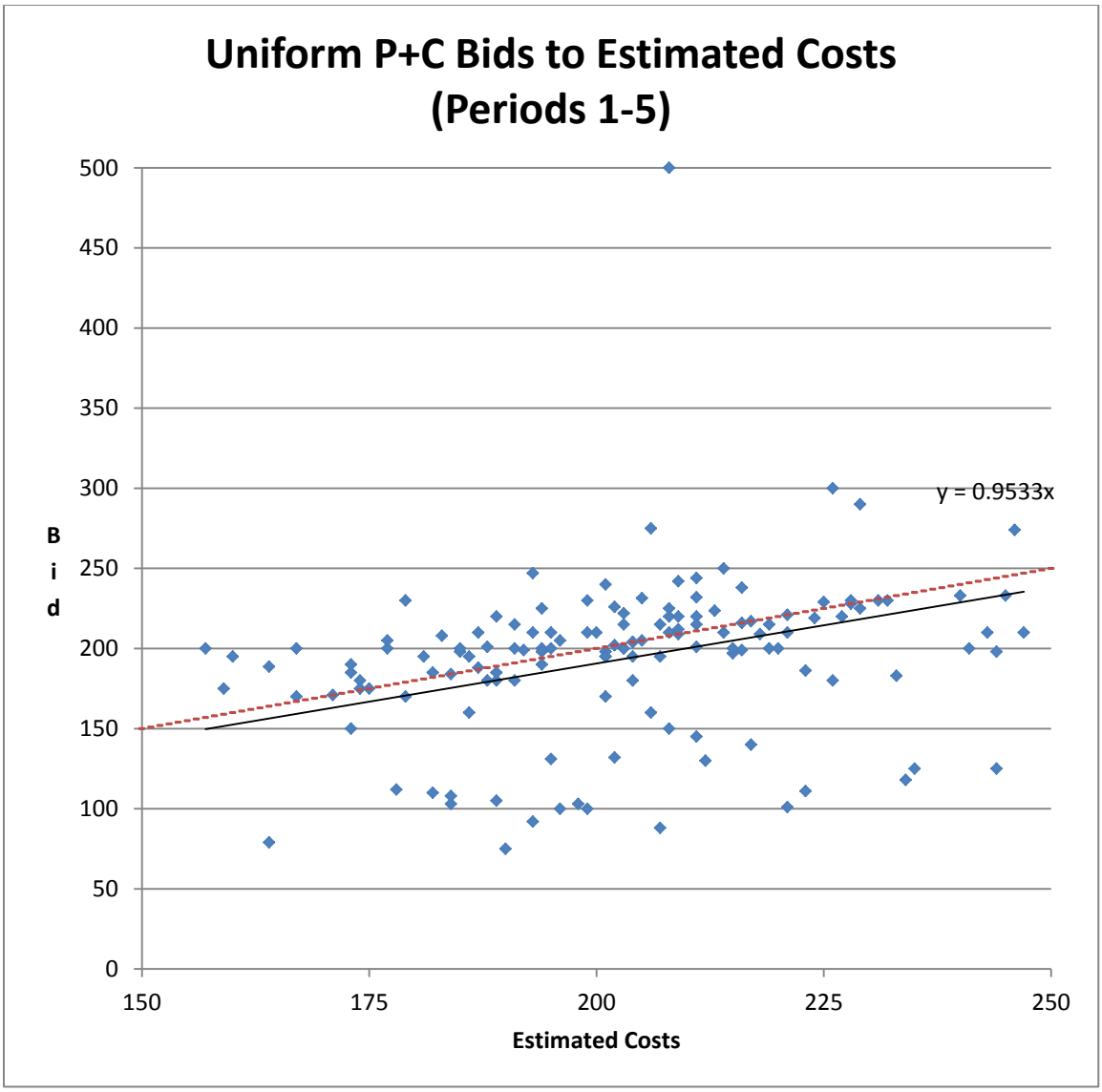
U_P+C	Bid
Average	197.0003
StdDev.s	50.32774
Count	836
StdErr	1.740621

Table 12. Uniform private and common bid to total cost



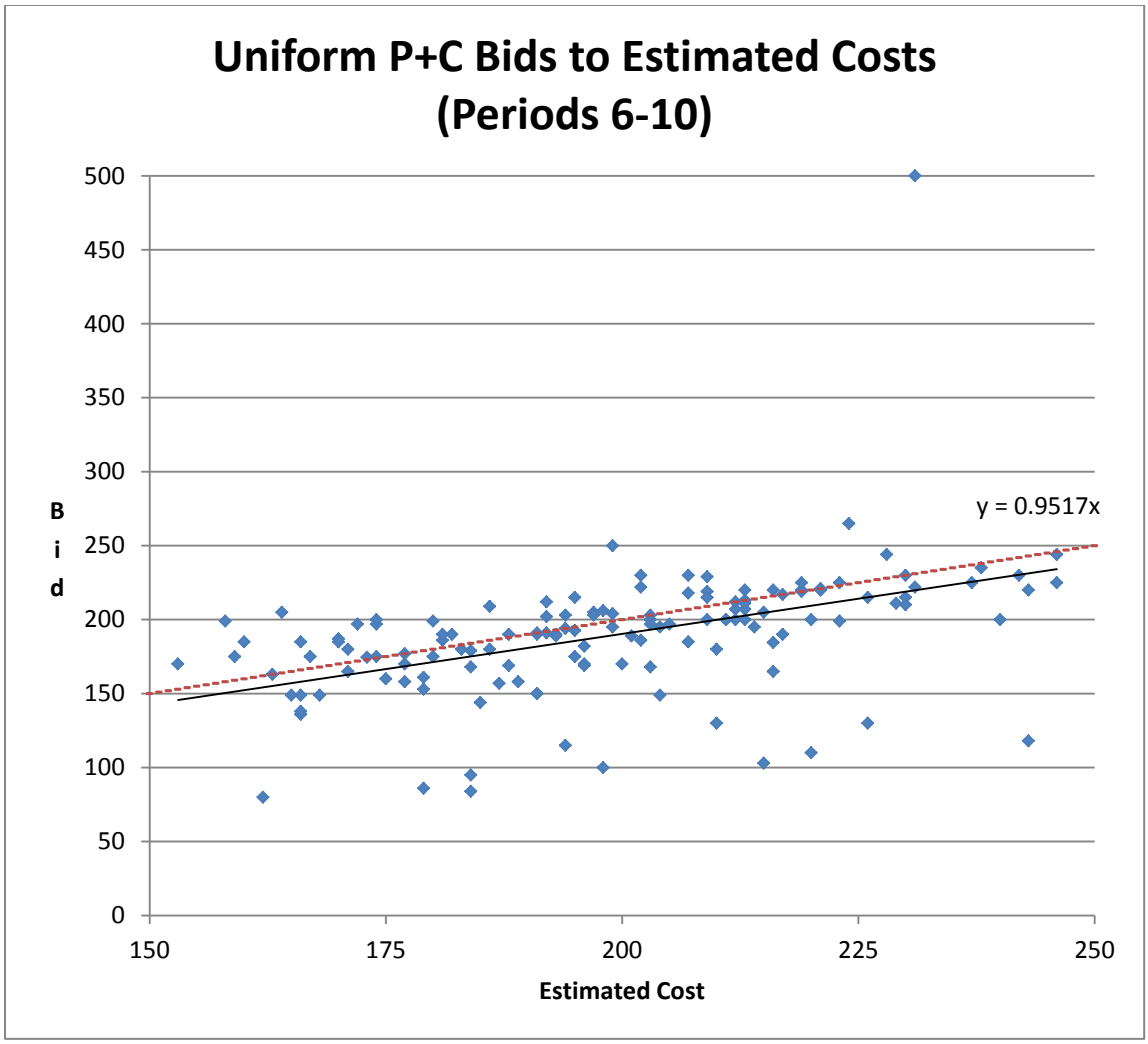
U_P+C	Bid
Average	197.0003
Stddev.s	50.32774
Count	836
StdErr	1.740621

Table 13. Uniform private and common bid to estimated total cost



U_P+C	
1 to 5	Bid
Average	193.94
StdDev.s	49.94
Count	140
StdErr	4.2209

Table 14. Uniform private and common bid to estimated total cost (periods 1 to 5)

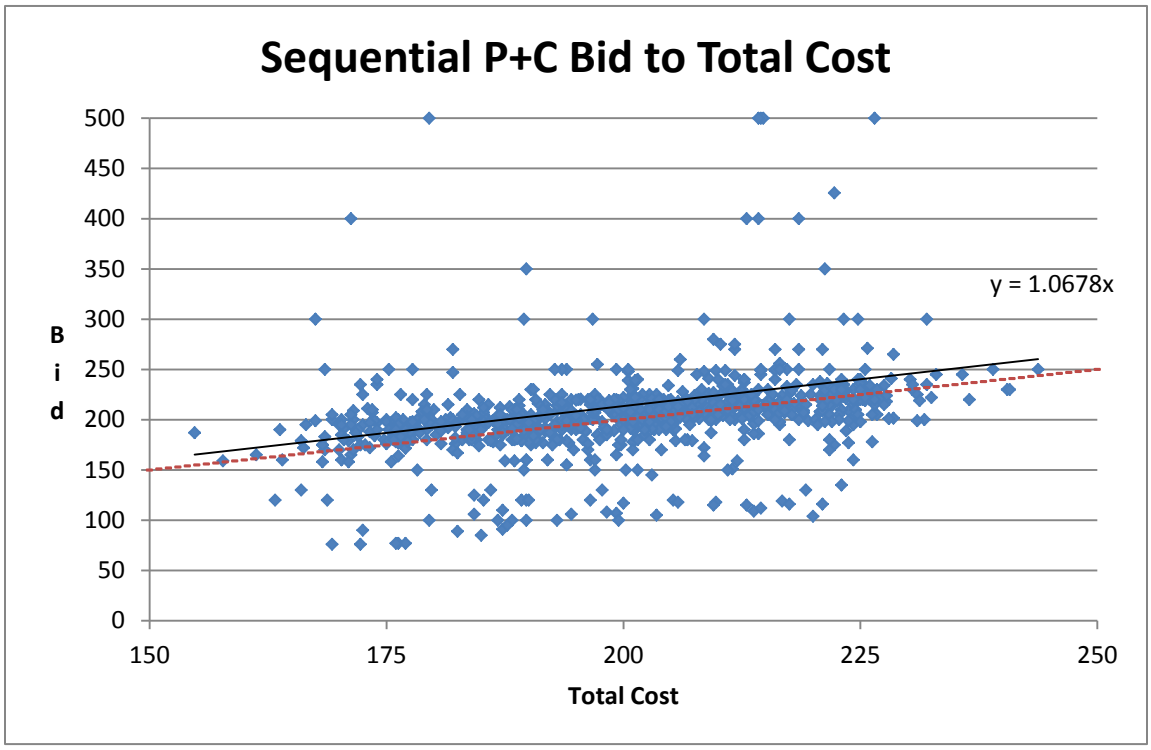


U_P+C	
6 to 10	Bid
Average	189.66
StdDev.s	43.45
Count	140
StdErr	3.6723

Table 15. Uniform private and common bid to estimated total cost (periods 6 to 10)

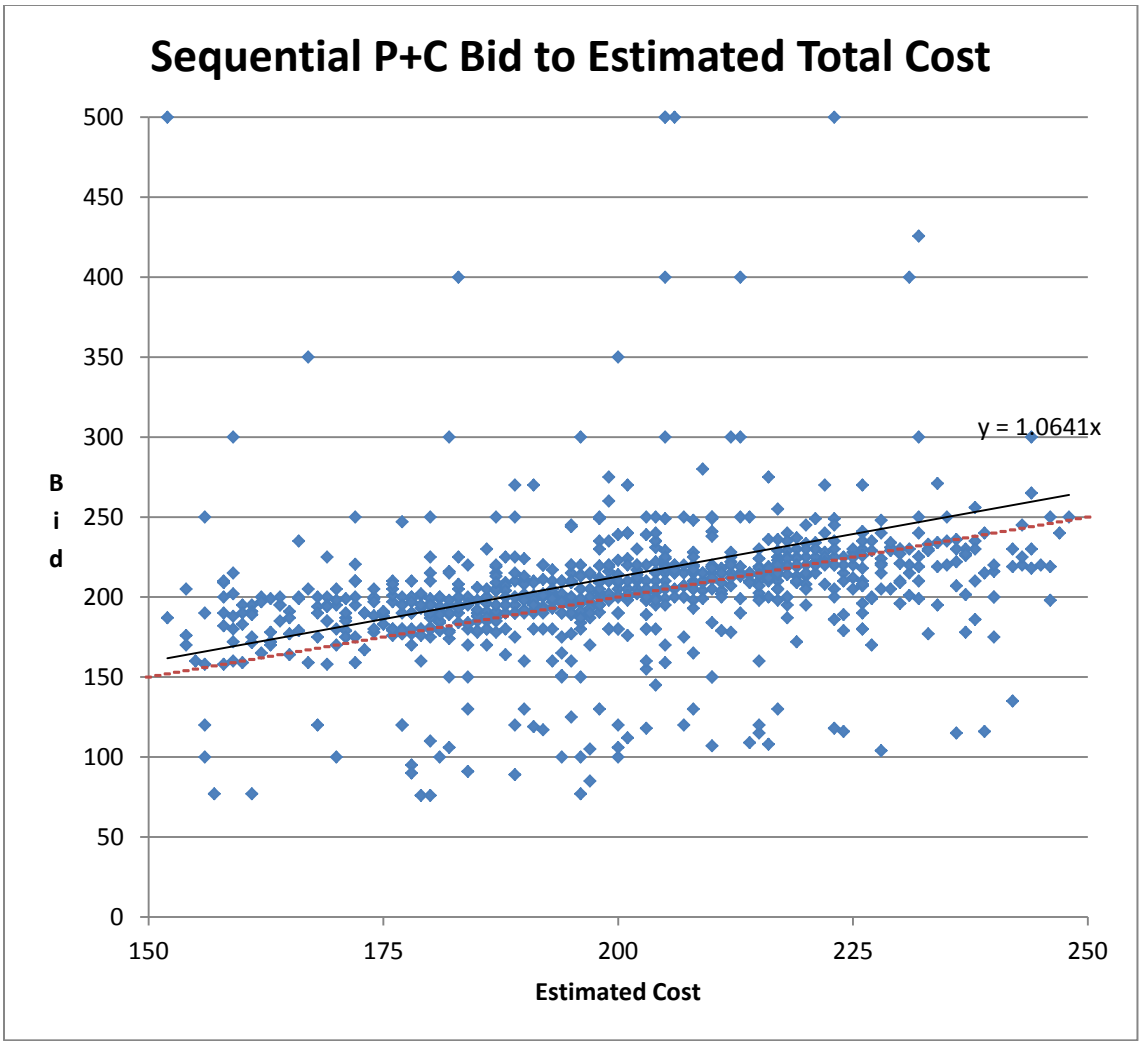
3. Sequential Private and Common Value

Sequential treatment bidding had the most variability in bidding strategies. Players could see the bids of their competitors in real time, and this generally caused most players to become less efficient. On average, the subjects bid roughly 6.8% over their total cost and 6.4% over their estimated cost. The sequential format had the highest markup percent of the three private plus common treatments (Tables 16 to 19).



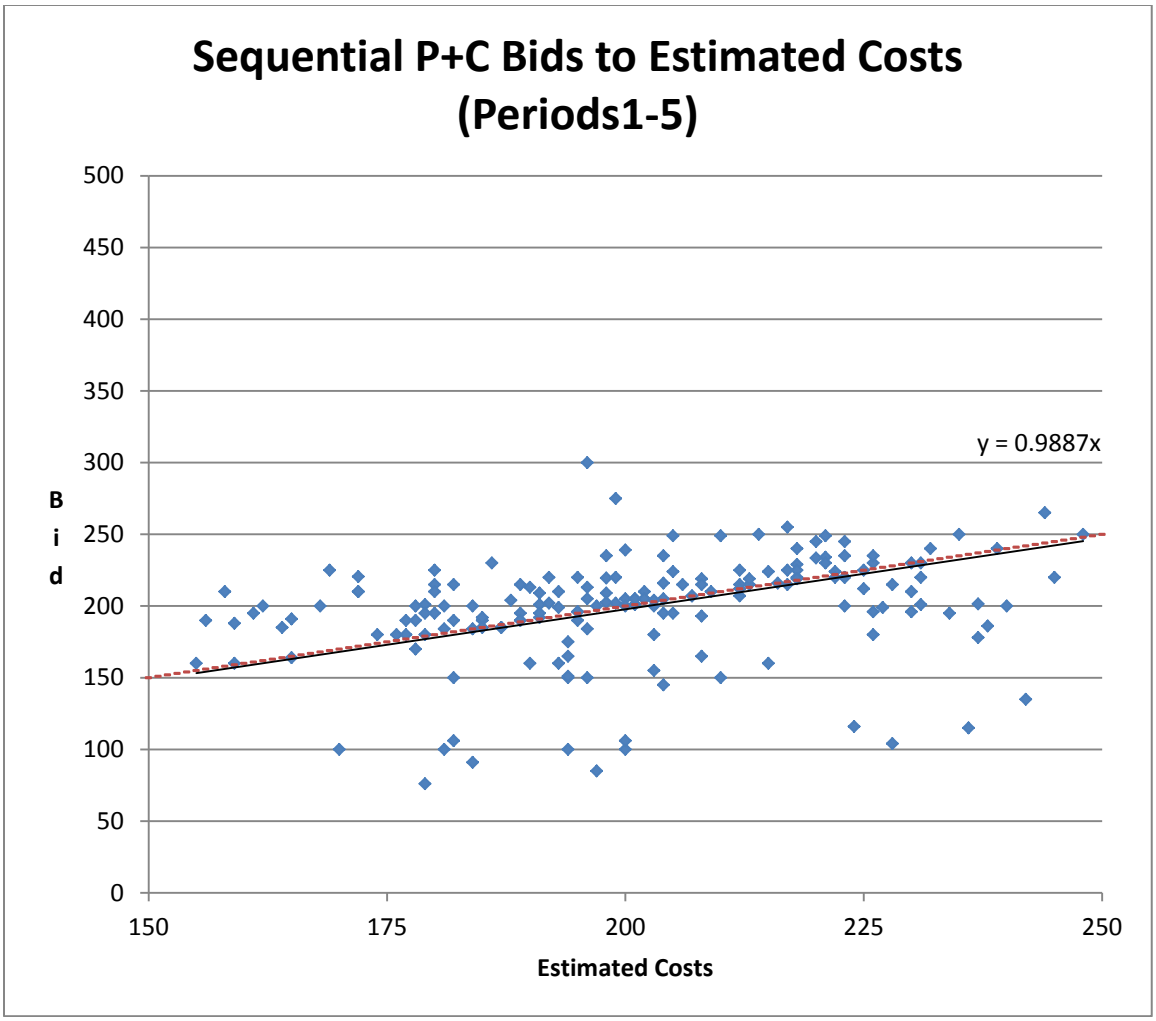
S_P+C	Bid
Average	213.462
StdDev.s	88.12394
Count	880
StdErr	2.970658

Table 16. Sequential private and common bid to total cost



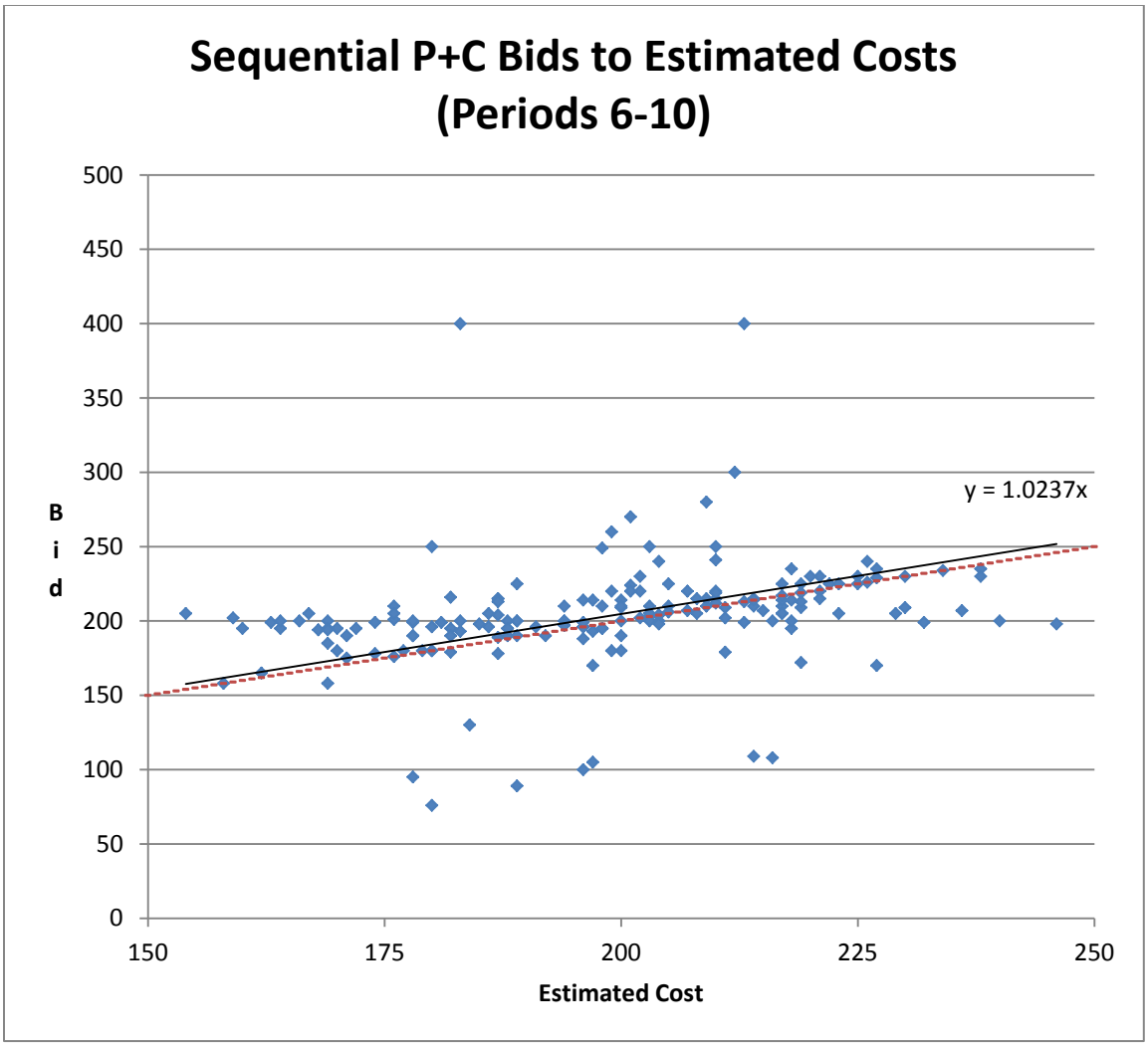
S_P+C	Bid
Average	213.462
Stddev.s	88.12394
Count	880
StdErr	2.970658

Table 17. Sequential private and common bid to estimated total cost



S_P+C	
1 to 5	Bid
Average	200.12
StdDev.s	43.86
Count	180
StdErr	3.2692

Table 18. Sequential private and common bid to estimated total cost (periods 1 to 5)

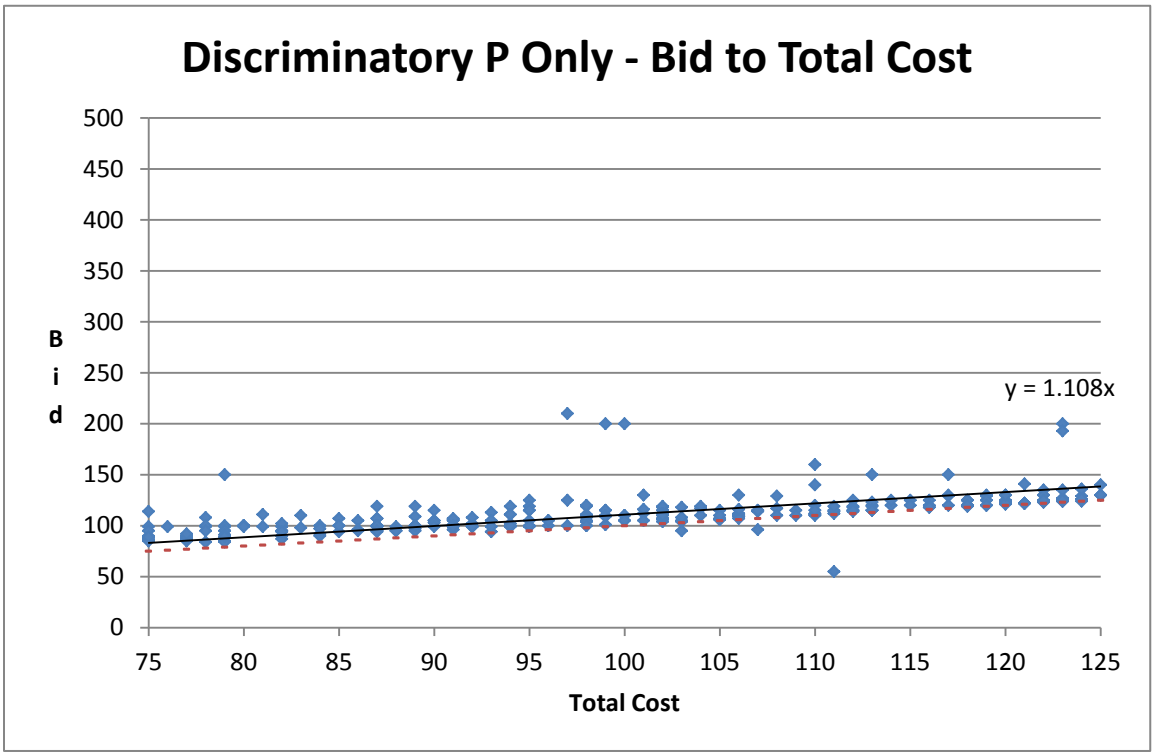


S_P+C	
6 to 10	Bid
Average	204.19
StdDev.s	36.34
Count	180
StdErr	2.7089

Table 19. Sequential private and common bid to estimated total cost (periods 6 to 10)

4. Discriminatory Private Value

Discriminatory private value auctions could be classified as the most simplistic treatment that was conducted. A player simply had a private value to deal with and their bids should be high enough to cover their costs and provide a marginal profit. The experiment showed that players generally required about a 10.8% markup over their cost (Table 20).

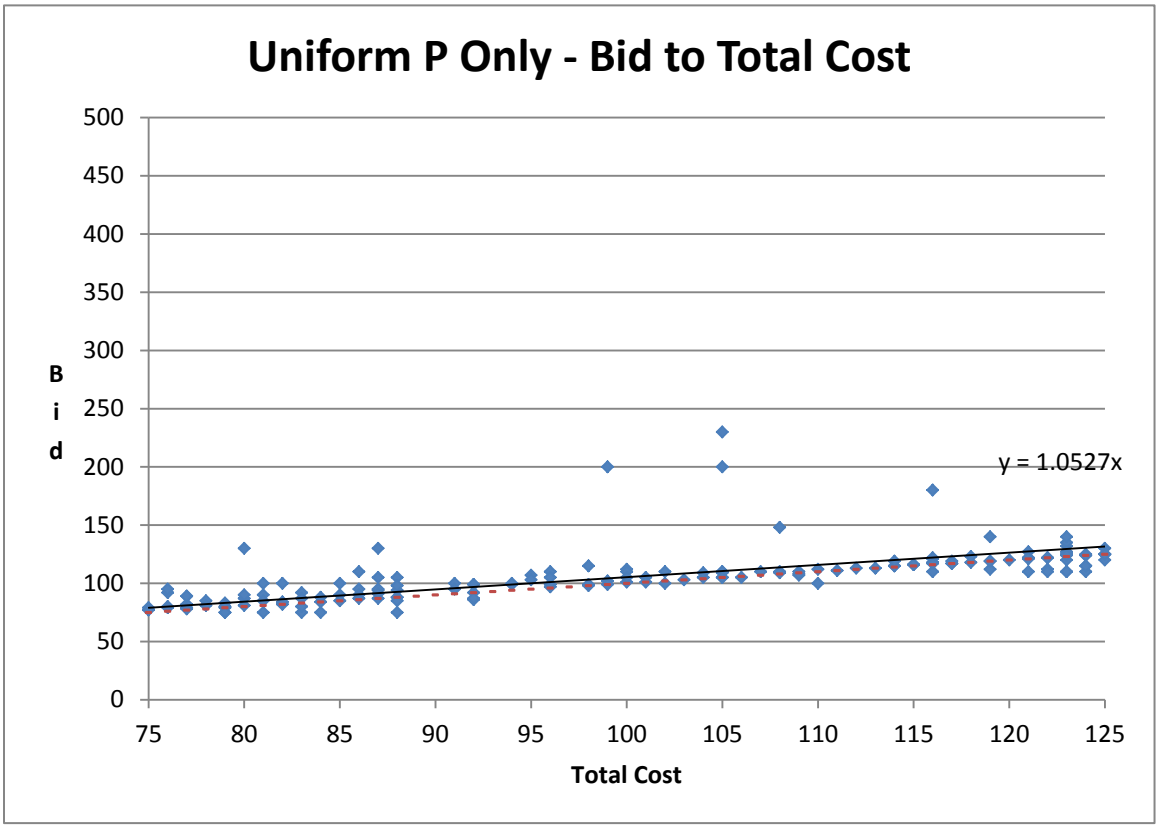


D_P	Bid
Average	111.675
StdDev.s	18.20251
Count	280
StdErr	1.087808

Table 20. Discriminatory private value bid to total cost

5. Uniform Private Value

Uniform private value auctions were also one of the simpler forms of the treatment types. It is Nash equilibrium to bid truthfully in this auction format, but we see about a 5.2% markup in their bids (Table 21).

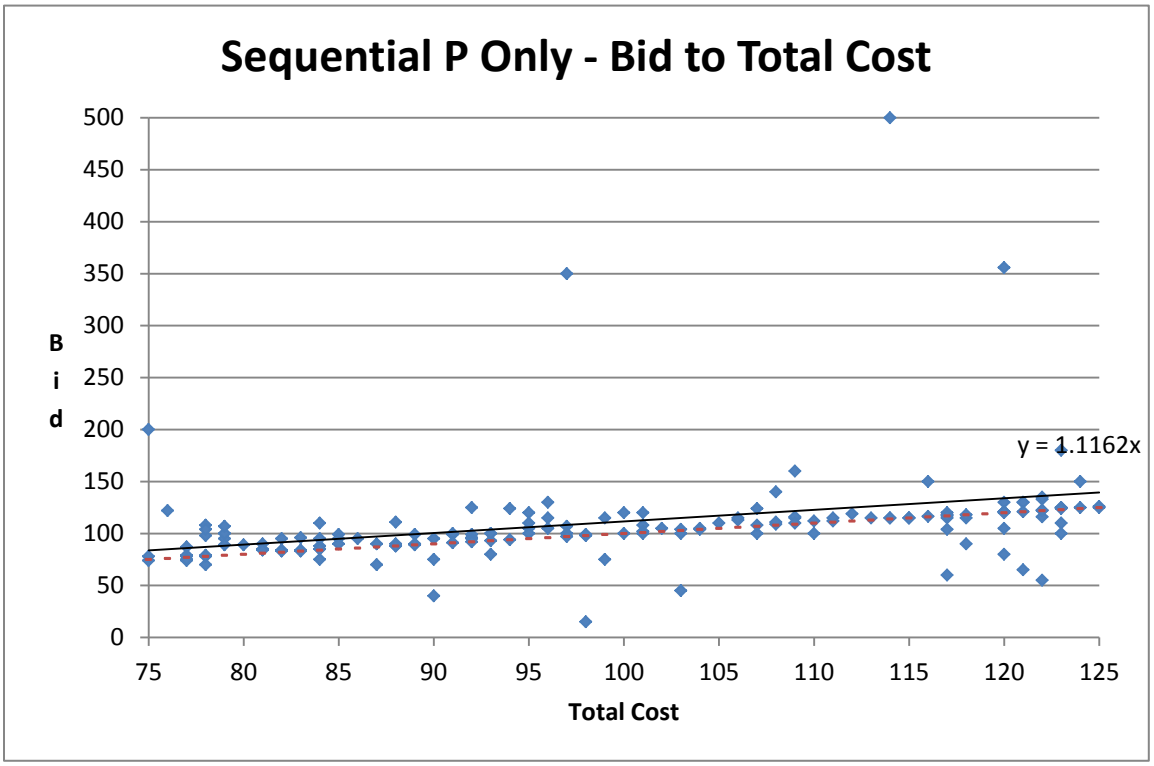


U_P	Bid
Average	106.5875
StdDev.s	22.45874
Count	160
StdErr	1.775519

Table 21. Uniform private value bid to total cost

6. Sequential Private Only

Sequential again has a high variability with respect to bidding behavior. There are also many more unexplainable bids in this treatment format. On average however, players valued their bids at roughly 11.6% over their private value costs (Table 22).



S_P	Bid
Average	112.6946
StdDev.s	66.81282
Count	160
StdErr	5.282018

Table 22. Sequential private value bid to total cost

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VII. CONCLUSION

Fiscal limitations may force changes to the way retention bonuses are allocated in the Navy. Using an auction format for the decision of what someone would ultimately be paid for retention is one alternative to the current system. Our research was focused on comparing three auction formats and determining how efficient they were as well as what their cost would be to the government.

We designed an experiment where we simulated the auction formats on a computer program and had individuals participate, taking on the role of a fictitious company selling services to an entity. The auctions were a reverse procurement style where bidders attempted to win by undercutting their competitors and yet still make a profit based on their private and common costs. We ran multiple rounds to provide a touch of a learning aspect and then were able to see those trends in the data.

We found that overall sealed bid discriminatory was the most effective auction from the perspective of the government. It had a significant procurement cost savings of 5.1% over sealed bid uniform, and a 10.1% edge over sequential uniform when common values were incorporated. Also, discriminatory was 9.5% better than uniform and 8.5% better than sequential for the private value only treatments.

In terms of efficiency (i.e., allocation of procurement to bidders with the lowest cost), discriminatory was also better than the two other treatment styles. When using common values, it clearly outperformed the other two. Using private only, uniform was slightly better, but the error between the two is very close. Sequential did relatively poorly in both cases.

We saw bidding behavior be very different for each treatment type as well. Subjects were generally more conservative when bidding on discriminatory projects, vice the uniform and sequential where they would be paid the first excluded bid.

An issue that was apparent in the data was that there must have been subjects who either did not fully understand what was being asked of them or intentionally gave bad data. This was evidenced by a few individuals bidding grossly below cost or bidding the max amount of fictitious currency for a single period toward the end of the auction. This data seems to be limited and should not have a major effect on the true data.

In conclusion, regardless of the auction format, practice is clearly needed. This benefits both the seller and the buyer, or the service members and the U.S. Navy. Our experimental data suggest that running a discriminatory auction may be the best out of the three formats. Finally, sequential auction format may cause “gaming,” by purposely losing with a high bid so that the winners can earn extra pay. We cannot make claim one way or another, however, whether we may see this gaming behavior in the larger-scale higher-stakes auction.

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